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Automation and Information Technology Solutions for Buildings and Homes

A Master's Thesis in Industrial Engineering
Espoo, 18th April 2008
Supervisor: Prof. Aarne Halme, Dr. Tech.
Instructor: Panu Harmo, MSc.

Abstract of the Master's Thesis

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This investigation is part of Master's of Science degree in Industrial Engineering at the Universidad Carlos III of Madrid. The work has been carried out at Automation Technology Laboratory, of Helsinki University of Technology (TKK).

This research is part of Assistive Automation project, which develops devices and systems assist independent living of elderly and disabled persons. The home automation system prototype is expected to increase the safety, comfort and independence of these people.

The main aim of the Thesis is to study and to implement standard communication protocols for the home automation system. Standards are essential in the development and proliferation of these systems. Open Building Information eXchange protocol is an emerging internet technology based communication protocol for building automation.

This approach has taken to us to enter collaboration with Computer Science and Engineering department in their oBIX based AVO project

This Thesis work develops a Linet network driven for an oBIX based server. The driver uses standard internet XML notation. The Linet interfaces were implemented in an oBIX compliant, Open Facility Management Server (OFMS). The work also includes a communication network study program code development, and Linet network study.

Keywords: *home automation, domotic, intelligent building, standard protocols, communication technology, home human environment, XML object programming.*

Acknowledgements

This Master’s Thesis has been carried out at the Automation Technology Laboratory of the Helsinki University of Technology during the time of Socrates/Erasmus exchange programme, which the author has participated in. This work is integrated within the Assistive Automation project.

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Eternally been thankful,

Fuenlabrada, 13th March 2007

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CD: other contents of the Master thesis

This CD contains the source code with all the files necessaries to execute the Master Thesis application. It is composed with three folders. Each one of these folders contains different classified information.

First of them is “*Adapter Programs*” folder. This has inside other three own folders. These three folders are made up by Master Thesis application. Division are according to the program structure, such as larger explained in chapter 8.

Second folder is titled “*Application Format with the Hannu Jarvinen programs*”. This contains the Hannu Jarvinen, from the other Department, application with the oFMS version used when the whole application was tested over the end of August.

Third folder is “Tools” and can be supposed contains the main tools used in this programming application development, such as both of the oBIX version used and the oBIX framework.

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Terms and acronyms

ACSE: Association Control Service Element.
A/D: Analog/Digital.
ADSL: Asymmetric Digital Subscriber Line.
ANSI/EIA/TIA: American National Standards Institute/ Electronic Industries Alliance/ Telecommunications Industry Association.
API: Application Program Interface.
ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning.
A/V: Audio/Video.
AVO: from Open Building Management Server, this in finish language is translated as "Avoin Kiinteistönhallintapavelin".

BACnet: Building Automation and Control NETworks.
Bluetooth: open specification for short-range communications of data, voice and video between electronic devices.

C#: a standardized imperative computer programming language.
CABA: Continental Automated Building Association.
CAD: Computer Aided Design.
CAM: Computer Aided Manufacturing.
CAN: Controller, Cluster, or Campus Area Network.
CD: Compact Disc.
CEBus: Consumer Electronic BUS.
CENELEC: Comité Européen de Normalisation ELECtrotechnique.
CIM: Computer integrated manufacturing.
CIT: Common Infrastructures of Telecommunication.
CTN: Commuted telephony network.

DAN: Desk Area Network.
DDC: Direct Digital Control.
DLNA: Digital Living Network Alliance.
DIN: rail is a standardized 35 mm wide metal rail with hat-shaped cross section.
DVD: Digital Video Disc.
DVR: Digital Video Recorder.

Eclipse: an integrated development environment.
EHS: European Home System.
EIB: European Installation Bus.

FMS: Flexible manufacturing systems.
FTAM: File Transfer, Access, and Management.

GPRS: General Packet Radio Service.
GSM: Global System for Mobile communications.

HAN: Home Area Network.
HAVi: Home Audio Video interoperability.
HES: Home Electronic System.
HiFi: HIgh FIdelity.

HTTP: Hyper Text Transfer Protocol.
HUT: Helsinki University of Technology.
HVAC: Heating, Ventilating, and Air Conditioning.

IA: Information Appliances.
ICT: Information Communication Technology.
IDE: Integrated Development Environment
IEEE: Electrical and Electronic Engineer Institute.
IO: Input/Output.
IP: Internet Protocol.
IPv6: Internet Protocol version 6.
IrDA: Infrared Data Association.
ISDN: Integrated Services Digital Network.
ISO/IEC: International Standards Organization/ International Electro-technical Commission.
ISP: Internet Service Provider.
ISO: International Organization for Standardization.
IT: Information Technology.

Java: an object-oriented high level programming language.
Jini: network architecture for the construction of distributed systems.
JMX: Java Management eXtensions.
JNDI: Java Naming and Directory Interface.
JRE: Java Runtime Environment.
JSP: JavaServer Pages.
J2EE: Java platform, Enterprise Edition.

KNX: KoNneX.

LAN: Local Area Network.
LCD: Liquid Crystal Display.
LIC-04: Linet Controller model 04.
Linet: LIght control NETwork.
LN1003: Linet node.
LMDS: Local Multipoint Distribution Service.
LON: Local Operating Network.
Ludobot: is a type of artificial human companion, an entertainment robot.

MAN: Metropolitan Area Network.
Mozilla Firefox: a graphical web browser developed by the Mozilla Corporation.

NC: Numerically controlled.
NTSC: National Television Standards Committee.

OASIS: Organization for the Advancement of Structured Information Standards.
oBIX: open Building Information eXchange.
oFMS: open Facility Management Server.
OSGi: Open Services Gateway initiative.
OSI: Open Source Initiative.

PAL: Phase Alternating Line.

PAN: Personal Area Network.
PC: Personal Computer.
PDA: Personal Digital Assistance.
PDF: Portable Document Format.
PLC: Programmable Logic Controller.
PLCc: Power Line Carrier controller.
PVR: Personal Video Recorder.

REST: REpresentational State Transfer.
RF: Radio Frequency.
Rollo: ball-shaped robot developed t the Automation Technology Laboratory.
Rollootori: wheeled robot derived from the Rollo ball robot's design.

SAN: Storage, System, Server, or Small Area Network.
SCP: Simple Control Protocol.
SDK: Software Development Kit.
SIM: Subscriber Identity Module.
SMS: Short Message Service.
SOAP: Simple Object Access Protocol.
STOK: from finish "Sähköisen Talotekniikan Osaamis – ja Kehittämiskeskus" meaning electrical building services centre.

TC: Technical Committee.
TCP: Transmission Control Protocol.
TML: Telecommunication software and Multimedia Laboratory.

UDP: User Datagram Protocol.
UMTS: Universal Mobile Telecommunications Systems.
UPNP: Universal Plug and Play.
URI: Uniform Resource Identifier.
URL: Uniform Resource Locator.
UTP: Unshielded Twisted Pair.

VCR: Video Cassette Recorder.
VoIP: VOice Internet Protocol.
VPN: Virtual Private Network.

WAP: Wireless Access Point.
WAN: Wide Area Network.
WiFi: brand licensed by the WiFi Alliance to products which pass testing demonstrating that they implement a set of product compatibility standards for wireless local area networks based on the IEEE 802.11 specifications.
WLAN: Wireless Local Area Network.
Wopa: Work Partner.
WWW: World Wide Web.

XML: eXtensible Markup Language.
X10: international and open industry standard for communication among devices used for home automation and domotics.

Chapter 1

Introduction

In this chapter the thesis project scope and approach are explained. Project goals and background are fixed in the actual technology context too.

1.1 Assistive Technology

The Information Age has transformed the way in which humans communicate and interact with each other in almost every aspect. This new relationship between humans and technology has been an added convenience for some, and a sheer blessing for others. For those with physical and communication impairments, modern-day technology has transformed daily living into a journey toward capability instead of disability [1.1].

Assistive technology is a generic term that includes assistive, adaptive, and rehabilitative devices and the process used selecting, locating, and using them. Assistive technology promotes greater independence for people with disabilities by enabling them to perform tasks that they were formerly unable to accomplish, or had great difficulty accomplishing, by providing enhancements to or changed methods of interacting with the technology needed to accomplish such tasks [1.2]. According to disability advocates, technology is often created without regard to people with disabilities, creating unnecessary barriers to hundreds of millions of people.

Universal accessibility means greater usability, particularly for people with disabilities. But universally accessible technology yields great rewards to the typical user. One example is the “curb cuts” in the sidewalks or street crossing. While these curb cuts enable pedestrians with mobility impairments to cross the street, these also aid parents with carriages and strollers, shoppers with carts, and travellers and workers with pull-type bags.

As other example, the modern telephone is inaccessible to people who are deaf or hard of hearing. Combined with a text telephone, which converts typed characters into tones that may be sent over the telephone line, a deaf person is able to communicate immediately at a distance [1.3].

Also, a person with mobility impairment can have difficulty using calculators, among others. Speech recognition software could recognize short commands and make use calculators and other technological tools easier.

There are great numbers of ways to help disability people with technology. Many of them still developing, but each day they appear as complete solutions to help disability people in order to do their more attainable or easier their daily tasks.

1.2 The Thesis Project Approach

Human communication is defined as “a two-way process by which one person stimulates meaning in the mind(s) of another person (or persons) through verbal and/or nonverbal messages” [1.4]. However communication covers a larger range around human environment and situation than a simple two-way process.

Communication is an inherent ability within the relations of living beings groups. Living beings observe and interact with their environment, obtaining information from them. This information source is considered such as other communication mean. Communication is extremely important for every species survival. The ability to extracted information from the environment and the faculty to transmit messages to each other are the keys for human development and world interpretation.

The process of sharing information is communication. In a simplistic form information is sent from a sender or encoder to a receiver or decoder. In a more complex format feedback links a sender to a receiver. All this requires symbolic activity, sometimes via a language.

Humans understand their environment through their senses. The human evolution has caused some losses in human senses and consequently affected to the contents of world perception. Ageing is other way which the world perception can be reduced [1.5]. At the same time language and intelligence tools advanced. Technology advances have even further increased human abilities (microscope, telescope, and a wide catalogue of different measurement sensors).

The humans communication continues to evolve been driven mostly by technology developments. Mobile phone technology and the new SMS language that eliminates letters to shorten words and meaning to acronyms, in order to economize SMS space, is a clear example of this case [1.6].

The communication evolution has differentiated humans from other living beings. At the same time humans learned to control the environment through human-environment communication. This human-environment communication is understood as human interaction with his surroundings. The further development is environment control aided by communication. The final development is environment auto-control designed by humans. The main technologies for these controls are robotic, telecommunications, and automation.

The environment considered in this study is the residential environment. Although transportation and industrial surroundings share some features with residential environments. This residential environment technology is frequently named Home Automation or Domotics. Human’s interaction with his environment is continuous day by day, getting information from home, office, shopping centre....This information exchange between human and his environment is understood as communication, which approach the project within an Automation Building area. The main idea is to make a standardized and extensible communication solution in order to cover mentioned human-environment relation.

1.3 Assistive system projects at automation technology laboratory of TKK project

Earlier researches from the laboratory had been carried out lower the main areas that cover the human communication and environment interaction. These researches developed Robotic, Automation and ICT (Information Communication Technology) works.

1.3.1 Part of a larger project

An earlier work in automation building field at automation technology laboratory of TKK deals with OSGi system (Open Services Gateway initiative) [1.7]. The OSGi Alliance is a worldwide consortium of technology innovators that advances a process to assure interoperability of applications and services based on its component integration platform. OSGi target is to define and promote an open standard in order to connect the offered services from metropolitan networks (WAN) and local networks (LAN) or domotics (LON). It facilitates the connection of intelligent devices inside home or office with external services offered through Internet.

The use of this type of system offers a wide range of advantages. Time-to-market and development costs are reduced, because it enables integration of pre-built and pre-tested modules. It reduces maintenance costs and provides aftermarket opportunities because networks are used to dynamically update or deliver services and applications in the field.

This thesis project uses a network already installed at the laboratory, the Linet network. Appendix B contains a brief Linet explanation. The Linet network was previously used in a home automation project called *TerveTaas* [1.8].

This thesis project collaborated with TKK's Telecommunication Software and Multimedia laboratory AVO (Avoin Kiinteistönhallintapavelin) project. The goal of the AVO project is build a standard interface that will be the communication key between a fixed network device and human control through a web server interface.

This application framework is a standardized method for communication and interaction between humans and their environment. The two way communication informs about the sensor states and transmits orders to the networked devices.

1.3.2 Assistive System Development

Humans strive to improve the quality of their lives in many ways including using technology. The most technology advances have gone hand in hand with the industrial development started during the industrial revolution. Recently this is also occurring in some developing countries.

Military research continues to take an important place in the technologies development. Some technical development is being slowed down because of patent rights issues. Many of them belong to the army and government. On the other hand, sometimes this research couldn't be done without substantial institution investment [1.9], [1.10].

Nowadays this communicative and assistive technology is spreading more and more to other fields. These other focus areas are for example building [1.11], office [1.12] and homes automation and control. Comfort, safety, energy saving, environment protection, together with special cares for handicapped persons in daily lives, work and control applications are the main targets of this field.

Other technology application cases can be found in civil engineering [1.13], transport systems [1.14], independent stations and other constructions for example [1.15]. Some of these current areas have great importance in these days, like for example medicine and medical care [1.16]. Actually most medical operations couldn't be achieved safely without the support of advanced technology [Figure 3.6].

Making the world easier and improving control systems, all of them look out for solutions and improvements in everyday task, doing lighter the work and easier control systems. Saving energy, money and time are also important goals.

Other current application is great interest of the assistive technology into the home automation. This is growing importance since the increasing of elderly populations in the western countries and also to give the handicapped people a possibility to more comfortable and independent everyday.

Helsinki University of Technology is working in this field with some research about the assistive automation. The development of a prototype of domestic help system for these above mentioned sectors belongs to the *Automaatio Avuksi* (assistive automation) project. Some results of these studies are installed for testing and exhibition in the *Toimiva koti* (Functional Home) information centre in the city of Helsinki. A range of solutions and aids are displayed in this prototype apartment.

1.3.3 Rollo and Rollootori

Rollo (Figure 1.1) and its successor Rollootori (Figure 1.2), are domestic service robots developed at automation laboratory of TKK [1.17].

Both of them are part of am assistive home automation system:

- They can be mobile user interfaces to the integrated home system.
- They can be used as tools for remote monitoring of the house or for telepresence.
- They can perform certain surveillance and alarm task that pass unnoticed by other sensors.

Rollo is a ball-shaped robot in its fourth version. Its innovative ball-shape design consists of a body with all the components mounted (electronics, motor elements and batteries) in an inner body, which is enclosed in a transparent spherical plastic cover.

This cover permits clear vision and protects the components (camera, laser pointer, electronic displays, speaker and Ir receiver).

Figure 1.1: *Rollo the ball shaped-robot*

Other innovative feature is the motion system. The inner mechanics of the robot are attached to the metallic rim where two removable plastic hemispheres join forming the cover. The body can rotate around two axes producing the robot motions by moving centre of gravity to the derived direction.

Irregularities in the floor surface are a problem for motion control. To overcome the Rollo's limited motion control and manoeuvre capabilities a new Rollootori platform was developed. In the beginning Rollootori was made to be a platform to mount Rollo, reusing all the work done with Rollo. But with time they evolved to two completely different devices. Rollootori is a two-wheeled two motor drive robot equipped with two additional free turning wheels for support.

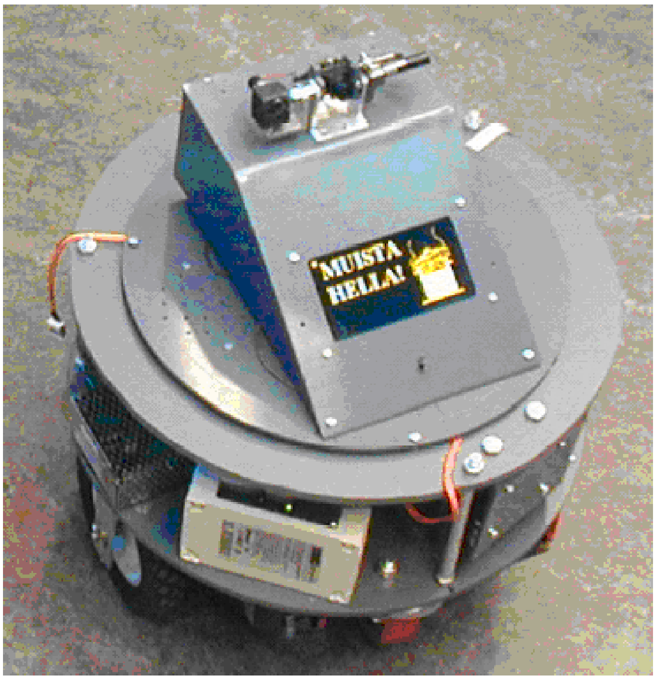


Figure 1.2*: Rollootori a four wheels robot*

The integration of the robots in the home system is based on wireless communication to a home server. Robot developments provide those with special properties treating to conserve the friendly interface. The server has a static map of the home environment. This gridded map contains information about the walls and other objects. Robots position themselves through image processing of tags located on the ceiling. This navigation system is easily extendible at any kind of buildings.

WorkPartner [Figure 1.3] is other mobile service robot of automation laboratory of TKK, also known as Wopa. It works interactively with people. WorkPartner is intended for everyday life tasks in outdoor environment. The robot locomotion system is hybrid. It allows motion with legs and/or wheels at the same time .WorkPartner works with a human-like two hand manipulator [1.18].

Figure 1.3: *Wopa, a robot for outdoor environment tasks*

1.4 Pursued objectives

This thesis project uses oBIX (open Building Information eXchange) [1.19] system in the same manner that the OSGi system was earlier used. This standardized oBIX system provides this application project with the needed tools, updates, continuality and services. oBIX details are collected in Appendix C.

oBIX is the chosen standard for this work, in order to develop new utilities within the installed network together with earlier devices from *Toimiva koti* development project.

The global project, named *AVO System*, looks for implanting an oBIX protocol system in a building environment solicited by the Korppoo city. This *AVO project* expects to build a human interface to control the installation.

The laboratory network together the installed devices are the test area to develop and test the XML adaptation work through oBIX configuration and programming. XML data format and oBIX protocol are both powerful tools easily extendible. The information supply in the other way will complete the second communication way. This way is not so clear due to Linet network properties. Other physical application with Coffee machine functionality has been planned.

Chapter 2

Home Automation Concepts

Main building automation concepts are explained in this section. Different kinds of automation buildings are differentiated. Present technology and developments in these areas try to be displayed in the next lines.

2.1 Different intelligent buildings

“Traditionally, a building was viewed as a passive housing or element of the workplace. Today, that has changed. A building is now recognized as a dynamic structure that supports the people and technologies working within its four walls. Consequently an intelligent building definition is as use of technology and process to create a building that is safer and more productive for its occupants and more operationally efficient for its owner” [2.1].

Intelligent building concept is abstract and considered depending of the application. In its most general sense it should mean a building that in some way can sense its environment, reach decisions about the state of that environment and communicate those decisions. In practice this should mean that a building can adjust some aspect of the interior or exterior environment in response to a change in some other aspect of that environment.

“To meet cotemporary and future needs, a building must establish an environment that is hospitable to those who live and work within it as well as to the changing technologies on which their productivity relies. To maintain an intelligent building is to control operating costs through technology and improved services” [2.2].

An intelligent building is one which provides a productive and cost-effective environment through optimization of its four basic elements, structure, systems, services, and management, and the interrelationship between them. Intelligent buildings help building owners, property managers, and occupants realize their goals in the areas of cost, comfort, convenience, safety, long-term flexibility, and marketability.

“The building intelligent is a measurement of the inhabitant and administration necessities satisfaction. Possibility to respect and adapt oneself to the environment around it is other measurement of a building intelligent” [2.3].

Three degrees of intelligent exist. These degrees are classified by the functions of facilities automation or from a technological point of view.

- Degree 1. Minimum or basic intelligent. A building automation basic system which is not integrated. For example, some presence sensor to open doors without any kind of network connection.
- Degree 2. Middle intelligent. The building has an integrated automation system. For example, systems have security and different places of the building information in order to control the main building utilities as HVAC, security doors system…
- Degree 3. Maximum or total intelligent. The building automation systems, activity and communications are completely integrated. This buildings increase degree 2 adding complete communication system, even with external points (internet, mobile lines…), in order to the complete building control.

Table 2.1 summarizes the general main targets pursued by intelligent buildings. More specific targets have importance in particular buildings depending on the applications [2.4].

Generals	- To satisfy the present and futures occupants, owners and building operators needs. - Flexibility, both structure, system and services. - Appropriate and correct architectonic design. - Building functionality. - Building structure and facilities modularity. - High comfort to the user. - Safety increase. - Work stimulation increase. - Give office a more human environment.
Technological	- Telecommunications advances availability. - Facilities automation. - Services integration.
Environmental	- A healthy building creation (without contaminant materials). - Energy saving. - Environment friendly.
Economic	- Operation support and cost reduction. - Economical profits. - The building lifespan increase. - Higher prices rents and sale prices. - Company prestige increase.

Table 2.1 Goals of intelligent buildings.

Generally three different terms are considered when talking about intelligent buildings. These are "Building Automation", "Office Automation" and "Home Automation" [Figure 2.1].

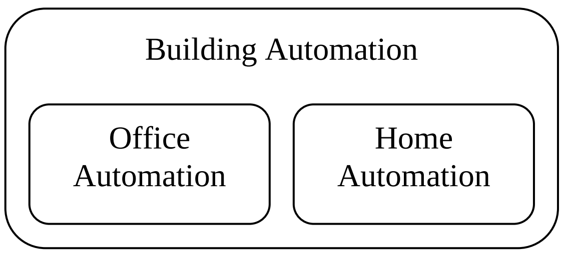


Figure 2.1 Intelligent buildings schema

2.2 Building Automation

“Building automation” is a programmed, computerized, intelligent network of electronic devices that monitor and control the mechanical and lighting systems in a building. The intent is to create an intelligent building and reduce energy and maintenance costs. It is the most global term and could be understood that building automation comprises the other two terms.

An example of the general functions governed by a building automation system is showed in figure 2.2. The network technology reduces installation and operational costs for buildings.

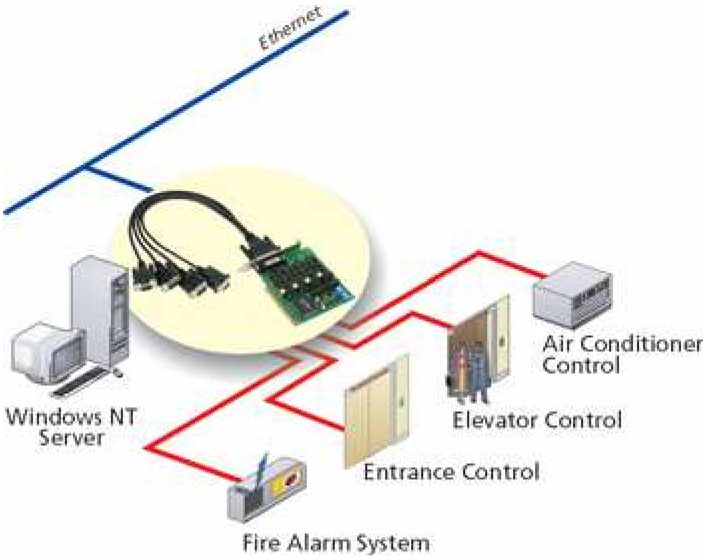


Figure 2.2 Building Automation management system

A building automation system gives building managers better control over resources, improving operational efficiency and reducing costs in the control room. With today’s data communication technology and sophisticated computer software, an intelligent building can be managed and monitored from a central location with a computerized building management system [2.5].

Bus systems are used to commanding and controlling building facilities. They are many electrical material manufacturer companies which have adopted the same communication protocol or look for converge among protocols. The aim is to be able to mix different producers components in the same installation.

The new technologies for buildings have to be considered in the designed and construction phases of a building. Even newer non-existing possibilities and options should be kept in mind when designing new buildings.

New buildings and renovations have different possibilities for networks and automation. In new buildings new networks and sensor can easily be designed and implemented. In renovations wiring can be more difficult and more radio frequency networks will be utilized.

2.3 Office Automation

Office automation was a popular term in the 1970s and 1980s as the desktop computer exploded onto the scene. Figure 2.3 shows the old concept which only includes all office functions, as dictation, typing, filing, copying, fax, Telex, microfilm and records management, telephone and telephone switchboard operations, fall into this category [2.6].

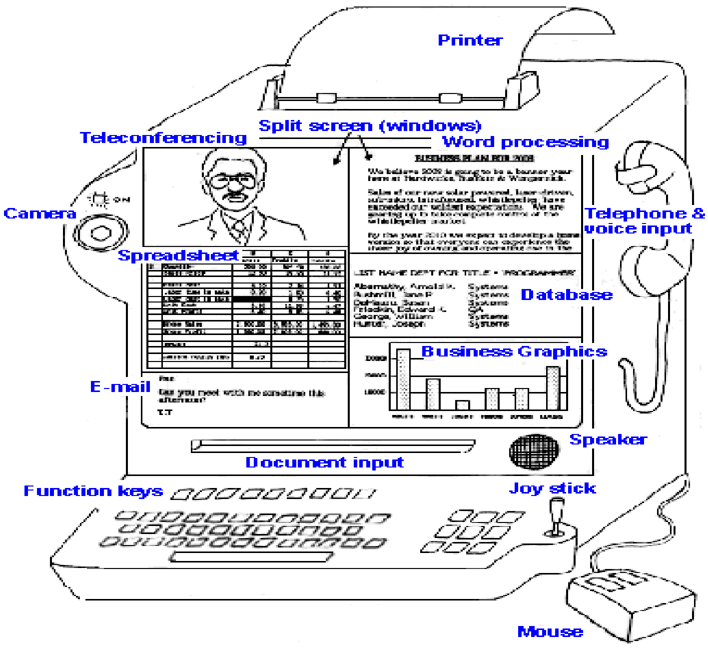


Figure 2.3 Drawing from 1981 to depict an integrated terminal in the office of the future

“Today office automation refers to the varied computer machinery and software used to digitally create, collect, store, manipulate, and relay office information needed for accomplishing basic tasks and goals. Raw data storage, electronic transfer, and the management of electronic business information comprise the basic activities of an office automation system.

The history of modern office automation began with the typewriter and the copy machine, which mechanized previously manual tasks. Today, however, office automation is increasingly understood as a term that refers not just to the mechanization of tasks but to the conversion of information to electronic form as well. The advent of the personal computer revolutionized office automation, and today, popular operating systems and user interfaces dominate office computer system. This revolution has been so complete, and has infiltrated so many areas of business, that almost all businesses use at least one commercial computer business application in the course of daily activity. Even the smallest companies commonly utilize computer technology to maintain financial records, inventory information, payroll records, and other pertinent business information.

Generally, there are three basic activities of an office automation system: data storage of information, data exchange, and data management. Within each broad application area, hardware and software combine to fulfil basic functions.

The backbone of office automation is a LAN, which allows users to transmit data, mail and even voice across the network. Office automation systems that include the ability to electronically share information between more than one user simultaneously are sometimes referred to as groupware systems. The functional effectiveness of such electronic sharing systems has been one factor in the growth of telecommuting as an option for workers" [2.7].

Examples of office automation include:

- Generate Microsoft Word documents or business forms from data stored in other applications such as Microsoft Access or Microsoft Excel.
- Generate presentations from external data.
- Automatically send emails to customers or groups in Microsoft Outlook.
- Create custom data entry mechanism for Microsoft Office documents.
- Create custom procedures for CAD (Computer Aided Design) programs including AutoCAD, Autodesk Inventor and SolidWorks.
- Maintain and organise data stored in Microsoft Excel or Microsoft Access.
- Extract data from PDF files for further processing.
- Create stand-alone executables to automate your office environment.

Businesses engaged in launching or upgrading office automation systems must consider a wide variety of factors that can influence the effectiveness of those systems. These factors include budgetary and physical space considerations, changes in communication infrastructure, and other considerations. But two factors that must be considered are employee training and proliferating office automation choices [2.8].

2.4 Home Automation or Domotics

When building automation is used in referring to homes it is often named as home automation. In the other hand term Inmotic is part of home automation. Inmotic is the equipment of installation management systems incorporation to third or industrial sector.

Day by day the term Domotics is growing in importance to substitute home automation. Domotics is the application of computer and robot technologies to domestic appliances. It is a portmanteau word formed from domus (Latin, meaning house) and robotics (from Czech word *robota*, meaning "forced labour"). This newer home automation synonymous term adapts oneself better to the home automation meaning.

Domotic is a field within building automation, specializing in the specific automation requirements of private homes and in the application of automation techniques for the comfort and security of its residents, including the integration of systems related to electricity, electronics, computing and telecommunications in home environments. Although many techniques used in building automation (such as light and climate control, control of doors and window shutters, security and surveillance systems, etc.)

are also used in domotic, additional domotics functionalities are more related with the resident comfort [2.9].

The main difference between building automation and home automation is, however, the human interface. In home automation, ergonomics is of particular importance: the control interface should be largely symbolic and self-explanatory.

A domotic system is a combination of hardware and software technologies, which can be classified into three categories [2.10]:

- Information appliances (IA): device that focuses on handling a particular type of information and related tasks. Typical devices could be smarphone and PDA. An IA is dedicated to performing a function and has the ability to share information with others [2.11].

- Home control network: the function of this is to control of all the electronic appliances and information appliances that form the home environment. Home control network try to bring the electronic appliances to the IA. It means that every electronic appliances can be controlled and share information with one another via the communication protocol in the control network.

- Software architecture of the domotic system: applying this technology tool the system achieves the goal “flexibility”. It is clear that the home environment is a complex environment and it is expected that an excellent domotics system should be a flexible system [2.11].

Chapter 3

Relevant Technologies to building automation

This Master's Thesis deals with the wide area of the automation and information technology solutions in buildings and homes. These technologies are introduced in order to better understand the specific field of this Master's Thesis.

3.1 Computer science

Computer science, or computing science, "is the study of the theoretical foundations of information and computation and their implementation and application in computer systems". "Computer science has many sub-fields; some emphasize the computation of specific results (such as computer graphics), while others (such as computational complexity theory) relate to properties of computational problems. Still others focus on the challenges in implementing computations" [3.1].

Among these computing sub-fields some are more essential for this master thesis work. This science deals with communication control among the different advices and controllers over the network. Computing science takes more importance if the home automation system consists of artificial intelligence module than a simple controller which handled the gadget information and operational decisions.

Despite its relatively short history as a formal academic discipline, computer science has made a number of fundamental contributions to science and society. These include:

- A formal definition of computation and computability, and proof that there are computationally unsolvable and intractable problems [3.2].
- The concept of a programming language, a tool for the precise expression of methodological information at various levels of abstraction [3.3].
- The theory and practise of compilers for translating between languages.
- Practical applications: the PC, the internet, search engines, scientific computing.

This science achievements will be connected to home automation areas. The computing level marks the future homes independency and auto control. "Despite its name, much of computer science does not involve the study of computers themselves. In fact, the renowned computer scientist Edsger Dijkstra is often quoted as saying, "*Computer science is no more about computer than astronomy is about telescopes*". The design and deployment of computers and computer systems is generally considered the province of disciplines other than computer science [3.4].

“Computer science is sometimes criticized as being insufficiently scientific. However, there has been much cross- fertilization of ideas between the various computer-related disciplines. Computer science research has also often crossed into other disciplines, such as artificial intelligence, cognitive science, physics (as quantum computing), and linguistics” [3.5].

Computer science is considered by some to have a much closer relationship with mathematics than many scientific disciplines. “Early computer science was strongly influenced by the work of mathematicians, and there continues to be a useful interchange of ideas between the two fields in areas such as mathematical logic, category theory, domain theory, and algebra” [3.6].

Nowadays newer systems have been programmed to control domotics applications. These systems handle the information treatment and gadgets control in domotics environment by means of computer science programming. Computer science is the key to link the information technologies.

Network communication pillars consist of computer science. Together with this other technology areas are equally based on computer science tools. Internet, education programs, simulation modules, design tools, biology and medicine, electric appliance control and more and more many of our environment functions are all based and positioned towards a future involved by computer science.

“The bond between engineering and computer sciences is even much stronger than between natural science disciplines and their engineering counterparts. For example, chemical engineering and chemistry, aircraft design and fluid dynamics, pharmacy and biology, and materials engineering and physics. This is because computer science has a strong heritage in electrical engineering and because many algorithmic methods were designed originally to solve engineering problems”. Examples include electronic circuits, telecommunications, engineering graphics, engineering design, systems engineering, fabrication, and manufacturing. Conversely, computers have become indispensable in many engineering disciplines as circuit simulators, finite-element simulators, flow-field simulators, graphics, CAD and CAM (Computer Aided Manufacturing) systems. “For these reasons, some observers like to say that computing is an engineering science” [3.7].

3.2 Automation

Automation (ancient Greek: self dictated) can be simply defined as “the level that human work is replaced by machines” [3.8]. The effectiveness of any automation system depends entirely on the quality of its underlying electrical, mechanical and control system.

If we look at history we can understand from how far this field really derives from. For centuries humans have built machines that imitate some parts of the human body. The ancient Egyptians united mechanical arms to their gods’ statues. These arms were handled by the priest, who clamoured for those motions to be inspired by the gods.

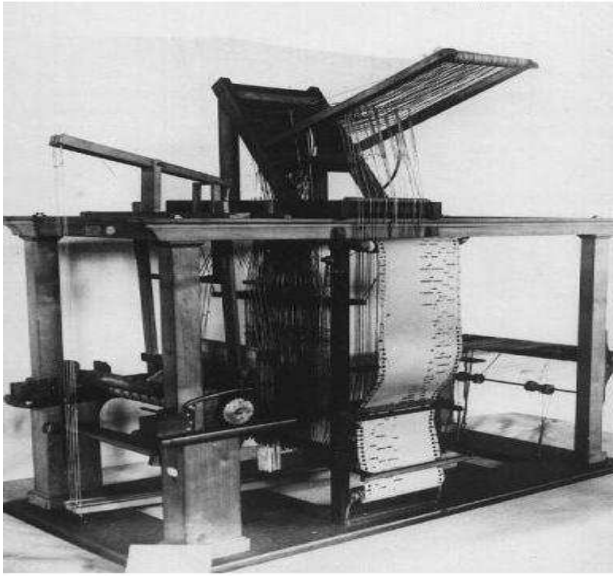


Figure3.1 Jacquard Loom an example of Industrial Revolution start.

Sometimes understood under roboticization, industrial automation and numerical control is the use of control systems such as computers to control industrial machinery and processes replacing human operators. In the scope of industrialization, automation is a step beyond mechanization [3.9]. Figure 3.1 exemplify this with a mechanized loom invented by Joseph Marie Jacquard in 1801 which used holes punched in pasteboard punched cards to control weaving of patterns in fabric [3.10]. The Jacquard loom is a prime example of early automation of the Industrial Revolution. Such with mechanical looms and weaving machines plain fabrics could be mass-produced at a much greater rate and lower cost than before.

Through all history humans have been looking for comfort to their daily tasks and lives. They have managed to improve the quality of their lives by developing automation. Automation technology went hand to hand with the development of other related fields such as powerful electronics computers, control tools, power transmission through gears and sensors technology.

Although automation "can play a major role in increasing productivity and reducing costs in services industries (as in the example of a retail store that installs bar code scanners in its checkout lanes) automation is most prevalent in manufacturing industries". Different automation platforms are [3.11]:

- Information technology (IT).
- Computer-aided manufacturing (CAM).
- Numerically controlled (NC) equipment.
- Robots.
- Flexible manufacturing systems (FMS).
- Computer integrated manufacturing (CIM).

There are still many jobs which are not threatened by automation. No device has been invented which can match the human accuracy in many tasks. Present cameras are much better (faster, without sleep necessity, work with less light…) than human eye. But even the admittedly handicapped human is able to identify and distinguish among far more scents than any automated device. "Human pattern recognition, language recognition, and language production ability is well beyond anything currently envisioned by automation engineers. Although it's quite clear that the researches in this sense make progress quickly" [3.12].

3.3 Communication networks

Communication networks are often defined as "a set of equipment and facilities that provides a service: the transfer of information between users located at various geographical points" [3.13]. They cover the telephone networks, the Internet, computer networks, television broadcast networks, cellular networks, etc. Communication networks provide systems flexibility and interconnectivity allowing the development of a multiplicity of new services.

3.3.1 Area networks

Over the years, the networking industry has coined terms like "LAN" and "WAN" attempting to define sensible categories for the major types of network designs. "Networking" refers specifically to a local area network (LAN). On the other hand, a wide area network (WAN) is commonly called a telecom network [3.14]. A third category, the MAN, also fit into this scheme as it too is centred on a distance-based concept. Figure 3.2 exemplifies clearly the communication area network infrastructure.

As technology improved, new types of networks appeared on the scene. These, too, became known as various types of "area networks" for consistency's sake, although distance no longer proved a useful differentiator.

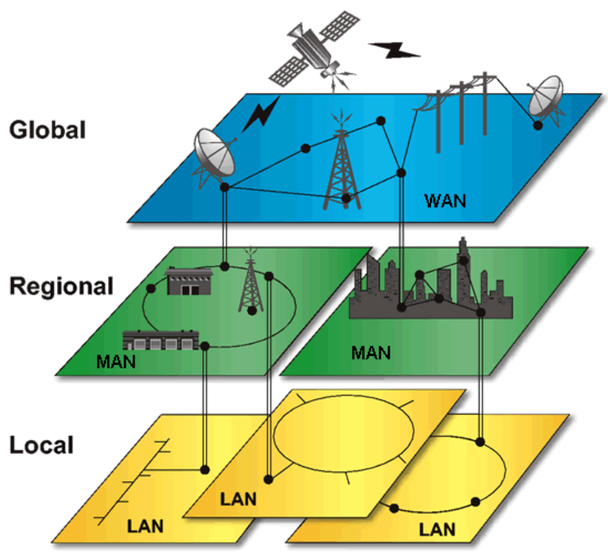


Figure 3.2 Communication infrastructure

3.3.2 LANs

In the modern office environment each worker is equipped with a personal computer containing its own disk drives and processor. Each of these computers can communicate with another by the way of a local area network, which is a computer network that covers a small area. As the name suggests, a LAN is a local, meaning that it is a proprietary system limited to a finite number of users.

The physical properties of a LAN include network access units (or interfaces) that connect the personal computer to the network. These units are actually interface cards installed on computer motherboards.

The next part of a LAN is the wiring, which provides the physical connection from one computer to another, and to printers and file servers. The properties of the wiring determine transmission speeds (coaxial cable, twisted wire pair, optical fibre cable, wireless...). Also the LAN topologies (line, ring, star…) influence the network constitution and capabilities [3.15].

LANs function because their transmission capacity is greater than any single terminal on the system. As a result, each station terminal can be offered a certain amount of time on the LAN, like a timesharing arrangement. Special software is usually utilized in LANs in order to eliminate collisions problems of messages.

As main difficulty, LANs are susceptible to many kinds of transmission errors. Electromagnetic interference from motors, power lines, and sources of static, as well as short from corrosion, can corrupt data. Software bugs and hardware failures can also introduce errors, as can irregularities in wiring and connections. LANs generally compensate for these errors by working off an uninterruptible power source, such as batteries, and using backup software to recall most recent activity and hold unsaved material. Security problems can also be an issue with LANs [3.16].

3.3.3 WANs

A WAN spans a large geographic area, such as a state, province or country. WANs often connect multiple smaller networks (figure 3.2), such as LANs or MANs.

The world’s most popular WAN is the Internet. Some segments of the Internet, like VPN-based extranets, are also WANs in themselves. Finally, many WANs are corporate or research networks that utilize leased lines.

WANs generally utilize different and much more expensive networking equipment than do LANs. “Residences typically employ one LAN connect to the Internet WAN via an Internet Service Provider (ISP) using a broadband modem. All computers on the home LAN can communicate directly with each other but must go through a central gateway, typically a broadband router, to reach ISP” [3.17].

For historical reasons, the industry refers to nearly every type of network as an “area network”. The other most commonly-discussed categories of computer networks are included in table 3.1 with a brief characteristic indication.

Acronym	Area Network	Description
WLAN	Wireless Local	Based on WiFi wireless network technology
MAN	Metropolitan	Spanning a physical area larger than a LAN but smaller than a WAN, such a city. A MAN is typically owned an operated by a single entity such as a government body or large corporation
SAN	Storage System Server Small	- Storage: Connects servers to data storage devices through a technology like Fibre Channel. - System: Links high performance computers with high-speed connections in a cluster configuration. Also known as Cluster Area Network.
PAN	Personal	Computer network organized around an individual person, typically involves a mobile computer, a cell phone and/or a handheld computing device (PDA).
DAN	Desk	System to enable the control of interconnections among A/V (Audio/Video) components in a room. Consists of a computer controlled A/V switch and software.
CAN	Controller Cluster Campus	-Controller: a serial bus network of microcontrollers that connects devices, sensors and actuators in a system or sub-system for real-time control applications. [3.18] - Campus: a network spanning multiple LANs but smaller than a MAN such as on a university or local business campus.

Table 3.1 Different area network types [3.19]

The importance of networks resides in its use in all areas of automation and technical systems. One network technology fields is the bus, the subsystem that transfers data in the form of electricity between computer components inside the computer and between computers. “The bus can even connect several peripherals using the same group of cables. Other key is the point to point topology of communication that happens when two hosts or terminal establishes communication solely between them” [3.20].

The wireless technology has acquired a high relevance due the new way possibilities that offers. Wireless technology gives us the possibility to work with mobile modules such as robots [3.21]. Other network characteristic will affect the system like Bandwidth.

The way data communications systems “talk to” each other is defined in a set of standards called “protocols”. Protocols work in a heritage starting at the top with the user’s program and ending at the bottom with plugs, socket and electrical signals.

Communication protocols are based in hardware and software that govern data transmission between computers. A protocol may define the packet structure of the data transmitted or the control commands that manage the session, or both. A protocol suite such as TCP/IP (Transmission Control Protocol/Internet Protocol) is made up of several levels of functionality. Learning the 7-layer protocol hierarchy, known as the “OSI model”, is essential for understanding protocols [3.22]. TCP/IP stack layer, which is based in OSI architecture, is clearly represented in figure 3.3.

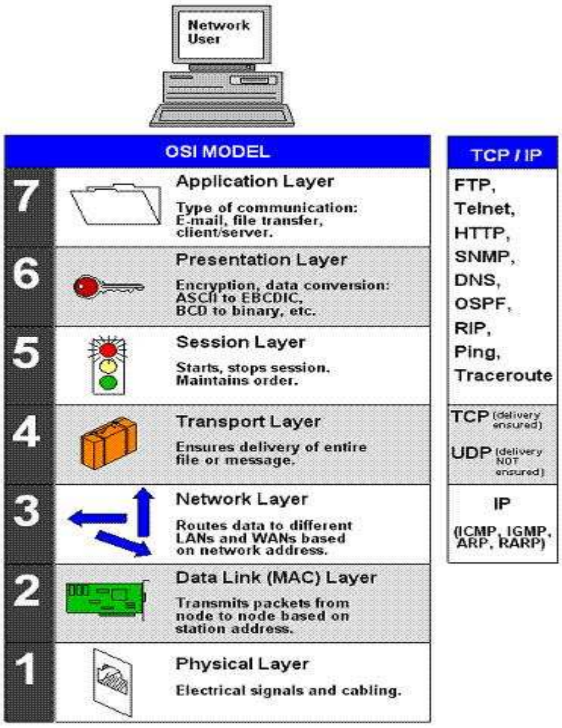


Figure 3.3 TCP/IP stack

3.4 Controller

The controller is intimately linked to the network chosen, even can suppose the appearance of some sub-controller handled nodes or devices composed in the system.
This element is usually considered such as the governor over the data transmission through the network, distributing, filtering and treating the environment information towards the rest of the system.

The controller is normally one or more programmable logic controllers, frequently companied by custom programming. PLCs come in a wide range of sizes and capabilities to control devices that are common in buildings.

A programmable controller includes a processor which executes a control to alter the state of an output image table stored in a read/write memory in response to the state of an input image table stored in memory. “An input/output scanner circuit connects directly to the read/write memory and periodically steals a memory cycle from the processors to couple the status of input and output devices with corresponding bits in the output image tables” [3.23].

PLC is a microprocessor used for automation of industrial processes, such as control machinery on factory assembly lines. “Unlike general purpose computers, the PLC is designed for extended temperature ranges, dirty or dusty conditions, immunity to electrical noise, and resistance to vibration and impact” [3.24].

In other hand the people understand “controller” with the system protocol that govern and drive the system. This protocol is the basis on which the system architecture is defined. This project own controller text lines are extended in the software document [3.25] and applicattion explained in chapter 6.

In engineering, actuators are a subdivision of transducers. They are devices which transform an input signal (mainly an electrical signal) into motion. Electrical motors, pneumatic actuators, hydraulic pistons, relays, comb drive, piezoelectric actuators, thermal bimorphs, digital micromirror devices and electro active polymers are some example of such actuators.

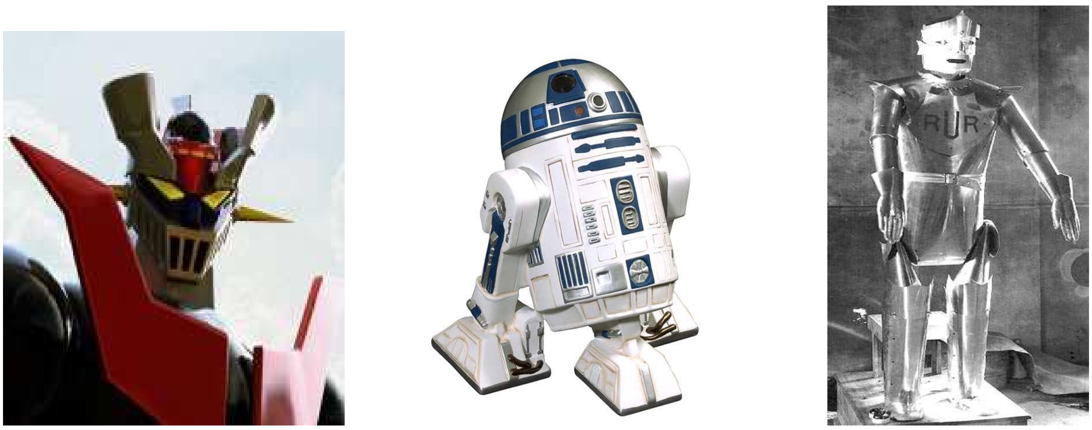
About the specified controller used in the application, the Linet controller within the Linet network and all the computer system needed in these functions, it will be explained in Appendix B.

3.5 Robotic

According to The Robot Institute of America definition a robot is considered: “A reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks”.

“Robot” word was introduced by Czech writer Karel Capek in his play R.U.R. (Rossum’s Universal Robots). Later the word “robotic” was introduced to science fiction. There it first appeared in the short story “Runaround” (1942, later included in Asimov’s famous book “I, Robot”) by Isaac Asimov. These events marked a breaking point in the “robotic” conception into the society.

Robot idea keeps in mind by society is usually different than real one [3.26]. Science fiction books and films are the main guilty of this confused idea. Three famous film’s robots compound Figure 3.4.



Figures 3.4 Film’s robots. On the left, Mazinger Z from Japanese manga and anime, in the centre, R2D2 from Star Wars saga, and on the right, first robot in cinema in R.U.R. film.

Briefly checking the history it could be understood as robot since the mathematician Greek Archytas of Tarentum invents (built a mechanical bird “the Pigeon” that is propelled by steam) approximately 350 B.C. At 1495 Leonardo DaVinci designed a mechanical device that looks like an armoured knight (figure 3.6). The mechanism inside “Leonardo’s robot” is designed to make the knight move as if there was a real person inside. At 1898 Nikola Tesla builds and demonstrates a remote controlled robot boat at Madison Square Garden, it was the earliest remote control vehicle built [3.27].


Figure 3.5. On the left, armoured robot knight designed by Leonardo DaVinci. On the right, remote-controlled medical robot.

The word robot is used to refer to a wide range of machines, the common feature of which is that they are all electro-mechanical devices capable of movement and can be used to perform physical tasks, mimics the human actions (in the physical sense or in the mental one) sometimes. This is the most popular way in which people have known the word “robot”.

Most correct robots classification separates them attending their function around human’s environment. Industrial, service, and personal robots are the three categories [3.28].

3.5.1 Industrial robots

An industrial robot is an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes which may be either fixed in place or mobile for use in industrial automation applications (definition from Robotic Industries Association) [3.29].

Robots are growing in complexity and their use in industry is becoming more widespread (figure 3.6). The main use of robots has so far been in the automation of mass production industries, where the same definable tasks must be performed repeatedly in exactly the same fashion. Robots are good for such tasks because the tasks can be accurately defined and must be performed on the same way every time, there is just little need for feedback to control the exact process being performed. Industrial Robots can be manufactured in a wide range of sizes and so they can handle much larger tasks than a human could [3.30].

3.5.2 Service robots

A robot which operates semi or fully autonomously to perform services useful to the well being of humans and equipment, excluding manufacturing operations (definition from International Federation of Robotics). This robot kind finds applications in “4D tasks” (dull, dangerous, dirty and dumb) and service in applications such as health care, entertainment, security, personal assistance, construction, and cleaning. Service robots are useful in environments which are unpleasant or dangerous for humans to work in, for example-bomb disposal, work in space or underwater, in mining, and for the cleaning of toxic waste.


Figure 3.6 On the left, ABB industrial robot IRB140. On the right, METAPO domestic robot CleanMate 365.

When accuracy work is needed, complex robots are remote-controlled by humans such as delicate operations. This example is illustrated in figure 3.6 where robot is handled by doctors working together.

Other growing field of service robotics is domestic robotics. Robots that perform simple tasks such as vacuum cleaning (figure 3.7) and grass cutting are now available in the market.

3.5.3 Personal robots

These are personal service robots that educate, assist, or entertain. They can be smart toys, robotics pets, or companion robots. Personal robots have the aim of providing companionship (social robots) or play partners (ludobots) to people. Humanoid robots are in development with the aim of being able to provide robotic functions in a form that may be more aesthetically pleasing to customers, thereby increasing the likelihood of them being accepted in society.

For education in schools and high schools and mechatronics training in companies robot kits are becoming more and more popular. Even in art festivals and at museums they are being found replacing guides.

Personal service robots operate in home automation environments with people. Thus the robot’s communication skills are important for an easy communication with people and the environment around them. Team or teams of robots and humans can be connected via electronic link. These teams of robots have capabilities beyond that of single robots, improving efficiency, harnessing physically-removed assets, and having synergies with other networked devices [3.31]. Exits some events examples of such robotic teams can be in application such as battle or sumo competition [3.32], and football and other sports games [3.33].

3.6 Sensors and Actuators

Both of them belong to the robotic and automation in general components, but they are considered as elements in the system. Individually they are to lack the power to operate. Orders and information treatment are necessary for actuator and sensor management.

An actuator is defined as “the mechanism by which an agent acts upon an environment”. The agent can be either an artificial intelligent actor or any other autonomous being (human, other animal, etc) which can be considered as a mechanism that puts something into automatic action. “A sensor is a device that responds to a physical stimulus, such us thermal energy, electromagnetic energy, acoustic energy, pressure, magnetism, or motion, by producing a signal, usually electrical” [3.34].

Robots can also be considered as actuators in an automation system. In these cases the robot’s mobility capability can out do the usability of fixed actuators or sensors.

Chapter 4

Domotic

The main structure of a domotic system is described in this chapter. Also the elements that compose this system type and its main uses and properties are briefly explained.

4.1 Domotic

The introduction of the new technologies at home is giving way to a new kind of information systems: the domotic systems. Nowadays this technology is entering homes and buildings gradually. In the past domotic systems have been seen in futuristic stories. However this technology is increasing its presence in homes and buildings continuously. Already a large number of domotic solutions exist on the market. Domotic develop has been delayed by lack of consensus on the domotic concept. Interesting interpretations have appeared faced with this lack of consensus. So domotic has not had a clear definition that allows its evolution until now [4.1].

Most modern houses have appliances that allow some degree of remote control. Domotics aims to integrate and extend this throughout the house. A house with a domotics system installed might have many computers, perhaps built into the walls, to allow the homeowner to control applications in any part of their house from any other part of the house.

According to one domotics definition: “Domotic is the automation technology applied to the technical management of houses and buildings. The domotics main objective is to improve the quality of life, to provide security, comfort and energy saving” [4.2]. An intelligent house consists of elements in a building that communicate with each other.

Domotic is the installation and integration of several networks and electronic device in home; these allow daily activities automation and local or remote housing or intelligent building control. For example, an isolated presence sensor can serve to open a door always when someone approaches. However, if the sensor is integrated in a network, it can provides with information about frequency of use, entrance rush hours, and others valuable data for other applications, such as maintaining doors open during greatest people flow to the building. Domotic is no services or isolated products, but simply the implementation and integration of all home devices.

Residential users are not always as skilled users of ICT as professional users. This lack of skill has to be taken into account in choosing the most appropriated technology and systems for the homeowners. The system must “feel” good since people spend much of their free time at home.

These domotic systems and technologies for homes are not reality yet. Increasing number of electronic devices with advanced controls and interfaces are being deployed in homes and houses. At the same time, the standardization of private communication's technologies, like wired Ethernet networks or WiFi wireless networks, had reduced costs to levels that allow their massive deployment.

Promoters provide their new buildings with domotic installations adding them value, which allow improving their sale. Furthermore, in one hand telecommunications companies, contents and services suppliers see the possibility of increase the offered services generating new deposits. On the other hand, services companies of water, light, electricity, security… open doors to rationalize their costs and to add value to the ultimate user [4.3].

There is no doubt that the more possibilities exist the more difficult entail their inter-connexion. So integrator companies labour is packs solutions with easy installation and simple maintenance. Other critical key is to be conscious that products are going to be able to share their functionalities and information with others. Then these products have to facility the data transfer, to permit remote management, and be able to offer ideally full solutions that require minimum user participation [4.4] , [4.5].

4.1.1 Components

To develop a domotic system demands defining functional specifications, selection of architecture system, programming of controllers, configuration of human-machine interfaces and installation and start up. Various components that provide sophisticated home automation link advanced electronic switching technology to existing residential voltage wiring for use in any residence [4.6].

- **Power Line Carrier Control**

Often power line carrier (PLCc) controllers transmit the unique codes over the alternating-current (ac) wiring network of the house directly to the PLCc receivers. PLCc components are easy to install and operate. "These PLCc components are used to switch lights and appliances from across the room, from another room, or from any convenient location in the house" [4.7].

- **Timer Controllers**

Most of us are familiar with a variety of programmable timers. "Timers have been on the market for decades and are useful for turning lights and smalls appliances on and off preset times of the day or the night". More advanced timer control units have far greater capabilities ranging from basics home control to domotic [4.8].

- **Computer Controllers**

Today, all domotic protocols are capable of utilizing an interface with personal computers. Computers used as domotic controllers provide enormous. Homeowners can create schedules for the automation system and "download" them automatically at predetermined times.

- **Wireless Remote Control**

"Several radio remote control devices are available, including multi-devices key fobs, handheld remotes, and wall switches". These remote controls allow homeowners to operate lights and appliances from their cars, backyards, or anywhere throughout the home [4.9]. "Using radio waves transmitted through walls and ceilings from anywhere inside or outside the home, these remote controls transmit command signals to a plug-in transceiver" [4.10].

4.1.2 Domotic Scope

A home's heating and air conditioning can also be automatically controlled for greater comfort and economy through the use of home automation. Kitchens are outfitted with microwaves ovens, convection ovens, dishwashers, and coffee makers, among other convenient, time-saving, and effort-saving appliances. Going hand in hand with the lighting programs are automation controls which will open and close designated drapes in the home, turn on the hot tub, or water the grass [4.11].

Technology controls are accessed with the touch of a button or remotely from telephones within home or anywhere in the world. Domotic systems are custom-designed to meet a variety of individual needs including convenience, energy savings [4.12], safety, and security. A simple telephone call will allow the homeowner to enter numeric codes through the number pad on the phone, gaining within to the control program. Currently there are three levels of interaction: home automation, systems integration, and intelligent home [4.13].

- **Home automation**

It is designed to turn a subsystem, or individual appliance, on or off according to a programmed time schedule. However, in this scheme, each device or subsystem is dealt with independently, with no two devices having a relationship with each other.

- **System integration**

It is designed to have multiple subsystems integrated into one controller. "The downside to this system is that each subsystem must still function only in the way in which the manufacturer intended it to operate". Basically, it is just remote, extending it to different locations [4.14].

- **Intelligent home**

In an intelligent home the manufactured product can be customized to meet the needs of the homeowner. The electronic architect in conjunction with the homeowner will write specific instructions to modify the product's use. "To take advantage of the latest technology, homeowners are expecting more from the builders than ever before. Builders, in order to partake of this lucrative new market, need to educate themselves and to train their workers predicting homeowner's expectations and moving forward to other possible" [4.15].

4.2 Telecommunication's Common Infrastructure

The free information access through telecommunication is a right of the citizens. A set of clear and explicitly rules must facilitate this citizen's right. These rules afford public installations and telecommunication networks to citizens.

Therefore these rules must to be collected and specified by each country within it own laws. The fulfilment of this set of rules in new constructions or full reforms predicts the advanced home's services development [4.16].

The Common Infrastructures of Telecommunication (CIT) pay attention to two main points [4.17]:

- Audible broadcasting and land television's signals reception and adaptation to up connexion points placed in different housings and locals. Audible broadcasting and satellite television to up cited connexion points too.
- Supply access to telephony service to public available and to telecommunication service of broadband, by means of the necessary infrastructure that allows the connexion to the different housings or locals to equipped operator's networks.

The basic issue at stake is the evolution of the set of rules; ensured CIT establishes the specified requirement of automation, energy's technical management, and security system's installation to housing and buildings, also known as domotic systems. Minimum requirement for domotic pre-installation are collected in the following basic elements list:

- ***Automation systems, energy management, and security for housings and building***. They are centralized or decentralized systems that are able to gather information from inputs and outputs (sensors or controls), process it, and send orders to actuators or resources. Security of these services is very important when using the Internet [4.18].
- ***Node***. They are each system units able to receive and process information communicating, when it is necessary, with other units or nodes within the own system.
- ***Actuator**s*. They are entrusted device to do some system's element control (electro-valve for water, gas… supply, motors for blinds, awnings, doors…, alarm sirens, light regulators…).
- ***Input devices***. Sensors, remote controls, keyboards or other device that send information to the nodes.

These elements can be independent or be combined in one or some distributed units, attending to the chosen system topology. According to this criterion two system rates can be recognized:

- ***Centralized systems***. All the components join to a central node that have at one's disposal control and command functions. This systems installation turns out easy, but has problems if has to connect a lot of elements. It is due to the star distribution, where it has to bring a cable to each element.

- ***Decentralized systems***. All the components share the same communication line, having at one's disposal control and command functions each one of them. Elements are distributed in bus. Each of them is able to its own control and actuation, allowing its programming individually.

4.2.1 Considered Services in CIT

The telecommunications services than can be supplied inside buildings, using CIT are classified in three types:

- ***Public available telephony service:*** In this case, the CIT function is to offer the service access to basic telephony (POTS) and to digital integrated service's network (ISDN).
- ***Audio broadcast and television service***: According is established, the CIT have to allow the receiving, adaptation and distribution of audio broadcast and television (TV) signals arriving of land emissions, including digital TV and satellite channels. The necessary infrastructure is formed by the following elements:
  - Signal capitation element's set.
  - Head equipment.
  - Network.
- ***Broad band's telecommunication services***: With this broadband network it is possible provide users with any service, from telephone to video under demand services and pay per view TV, all the way to high velocity Internet access.

4.3 Domotic in new or existing buildings

4.3.1 Domotic in new buildings

Domotic introduction in new buildings depends mainly on real estate builders. If users demand this kind of systems builders will install them gradually. Domotic introduction in new buildings is cheaper than in existing buildings, the situation is not far from promotions with these systems proliferation.

According to experts, the basic infrastructure needed for domotic housing, only increases the cost between 1-2% of average. This percentage is extremely low if everything improved to public attractive is pondered.

4.3.1.1 Domotic Project

A building automation had to follow a clear and detailed methodology in order to know what had happened and what is happening anytime, and even what will be happen in the future sometimes. As more complex installation as monitoring methods has more importance.

Domotic project can be divided in four phases: pre-study, definition, installation and delivery. The project has to cross through these phases which are collected in figure 4.1.

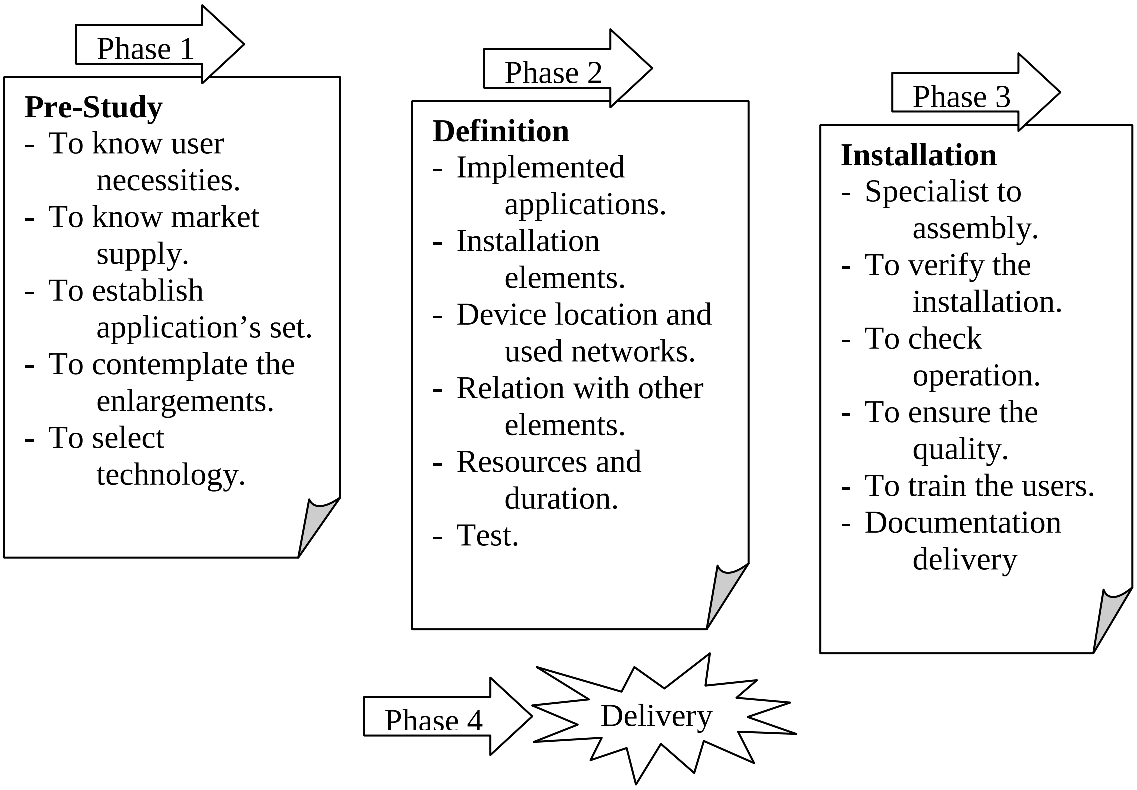


Figure 4.1 Domotic project methodology phases [4.19]

Offered applications, technology and supplying to use belong to the pre-study phase. This phase requires exhaustive market knowledge.

Used technology establishes software specific tools. These tools makes possible to determinate installation devices localization and configuration, planned devices inventory, global installation cost estimation…Software tools selection take high importance in order to saving cost.

4.3.2 Domotic in existing buildings

To introduce domotic in existing buildings all concepts already presented in domotic for new buildings are valid. Nevertheless the implementation decision depends solely of users or building owner.

Domotic introduction to existing housing is more expensive by diverse reasons:

- The user can't take advantage of device wholesale prices, unlike a building company.
- The integration of devices with the rest of installations is more complex.
- The interconnection networks of different devices have to be installed on top existing surfaces.
- The user is not experienced in design and installation of domotic system and must acquire expert's service.

4.3.2.1 System alternatives

Alternatives for communication networks for pre-existing building are fewer than for new buildings. This reason complicates many projects due to the necessity of brickwork to incorporate canalizations. Other possibility is to use mains voltage electrical networks that allow signal transmission in low speed together with supply power to the devices.

Communication network problems can be with maximum location flexibility with wireless technology. Wireless technology has disadvantages in communication security compared with wired systems. Supply power continues to be a problem, although many sensors can be battery powered.

Wireless technology allows domotic system device distribution with maximum ubiquity with quickly adaptation to changing needs. The drawback are less communication security and robustly, less distance between devices, less transmission speed (see Figure 4.2), and devices that cost slightly more.

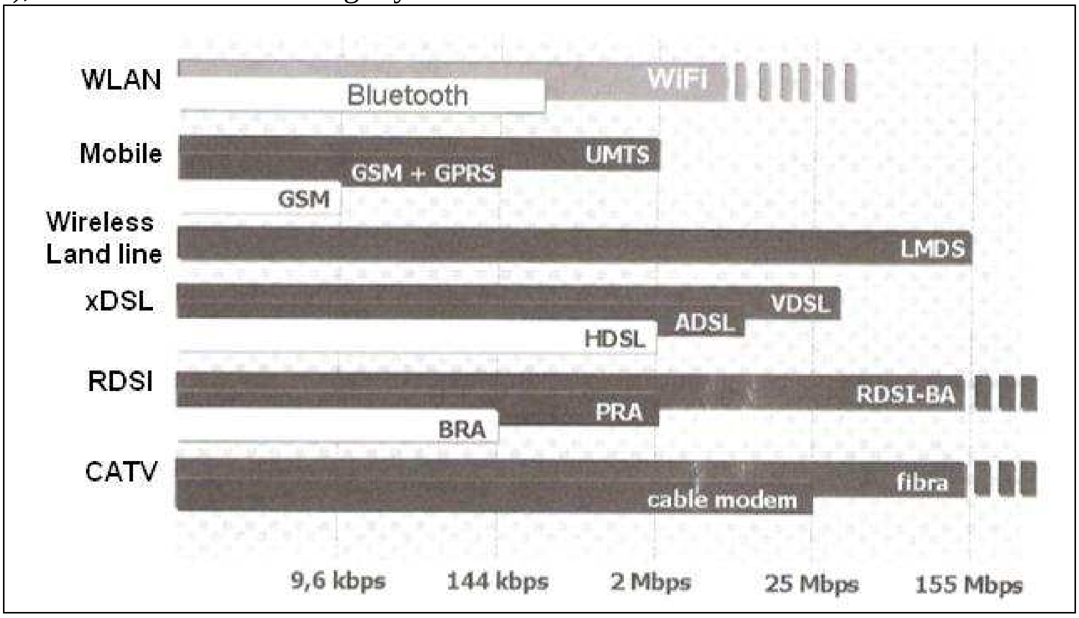


Figure 4.2 Speed comparison of wireless and wired networks

4.4 Intelligent building devices

Domotic house does not differ much from a traditional house when considering household appliances, water, gas, electricity or heating installations. Domotic allows, however, control, automation and cooperation of those devices and systems. This can increase the house value and increase the life quality security of the inhabitants.

A few years ago housings provide solely with pieces of furniture and some electrical devices as ovens, lights, radios, etc. Nowadays consumer electronics, informatics equipment, and electrical appliances incorporation have larger importance.

Introduction of domotic to buildings means bringing new elements to buildings. Typical domotic elements are described in the next pages.

4.4.1 Residential Gateway

Residential gateway is the interconnection device between different external access networks and intelligent building internal networks [4.20]. Despite of the name these gateways are not exclusive to homes, and they can be located in any other building type. An example of residential gateways is showed in figure 4.3.

Figure 4.3 RG2200 Residential gateway of Motorola offers bundled services voice, data and broadcast, and interactive video and entertainment services[4.21] .

Residential gateway will be generally installed (for instance, over shelves, television, or hang up from entrance corridor) by the broadband access operator for the user. The reason is that this gateway is the basic device from which network operators will be able to offer interactive and added value services to homes. This devices is intelligent routers that connects operator infrastructure to the home, establishing an interconnected network inside the building [4.22], [4.23]. With management software operators have a “front building door”, that enables them to configure, correct, and actualize remotely the access devices of the client network and to manage the engaged services [4.24].

These elements mean a “front door” to countless features that make buildings more proliferate, pleasant, functional and comfortable. Residential gateways allow full home connectivity with outer world, being able to tele-control electrical appliances, consumer electronic equipment, and PCs and much more [4.25].

4.4.1.1 Gateway Components

Residential gateways are part of digital convergence that also includes broadband Internet connections proliferation, PCs number rise in homes, and increase of new device and electrical appliances that need to be in network to implement new and useful features.

The main components that can be identified in gateways are:

- Physic ending of extern access and of internal distribution means.
- Protocol adaptation to every level.
- Own internal network management.
- Internal device management.
- Internal services management.
- Flow control in order to guarantee privacy and secure access.

4.4.1.2 Gateway Features

In order for residential gateways to be successful and to achieve massive installation they must have following features:

- Installation must to be simple. Ideally, the gateway should be completely “Plug & Play”, or at least its installation should be possible to any end user without the necessity to resort to an expert.
- Gateway must to be secure [4.26], preventing undesired accesses and fraudulent uses of the private networks. Gateways also have to cover user’s identification, data encryption, access registration, etc.
- Gateway must to allow preventive maintenance functions detecting errors in the own gateway or in any elements.
- Residential gateway must support different interfaces towards the outside and interior, that is to say, that as much offer interoperability to connect level, like transport level.
- An other basic characteristic is its ability to adapt to future changes in network standards and new interfaces. Open a modular architecture is needed where the new interfaces or functionalities can be done quickly without disturbing the existing ones.
- Capacity to support multiple services is also important. Gateway must have sufficient processing capacity and memory and a robust multitasking operating system that processes multiple task concurrently.

4.4.1.3 Gateway integration with other devices

Actually, all the residential gateway tasks can be performed in a home PC equipped with suitable additional hardware and software. However, a different device is necessary because the PCs are limited by:

- Instability. Windows based systems are often not ROM enough.
- Complexity. PC use requires moderate computer skills.
- Users reject to pay for additional PC performance.
- PC is a system very open. This is a problem for operators and service suppliers, who are averse to offer uncontrolled access to their information data systems.

Other possibility is that the residential gateway is included in the device that operators offer for broadband Internet access (modem, router, decoder, set-top-box, etc.). In fact, many ADSL (Asymmetric Digital Subscriber Line) routers offer already many communication ports such as WiFi, USB, and Ethernet. However, processing and memory needs in a residential gateway are greater than these devices can offer today [4.27].

4.4.1.4 Local Interfaces to the Gateway

By all the explained previously, it is clear that residential gateway will be a new device different of actual PCs, modems, ADSL routers, and centralized control systems. In fact, the gateway will be able to communicate with these devices and allow their control and configuration.

However, it is possible to access within the building all devices of common use through the gateway. The gateway, generally, does not have any contracted keyboard or screen that facilitates their control and configuration. The main reason for this is that the gateway offers a wide variety of standard interfaces for remote or local control, and there are many devices in the building, which have screen and keyboard.

A great debate exists at the present time over which interface is the most adequate for the user to locally manage his home resources, PC or TV. Other more alternative is a Web Pad.

Web Pad gains followers by its facility to be carried to any place of the house. A strong argument for the use of the TV is its greater penetration in homes. The ample experience of the computer science industry in the establishment of compatible standards and technologies for reasonable prices grants a clear advantage to the PC. Interface web of residential gateway let user access as much to it from the home interior as from outside, by means of movable PDA or telephones WAP [4.28].

4.4.1.5 OSGi Alliance

The OSGi Alliance (formerly known as the Open Services Gateway initiative) is an open standards organization founded in March 1999 by 15 multinational companies. “This is an independent non-profit corporation comprised of technology innovators and developers and focused on the interoperability of applications and services based on its component integration platform” [4.29].

The OSGi specification defines neither the hardware nor the physical cabling, but the necessary software architecture so that all services are executed without problems in the same platform. In this way, it allows any manufacturer, free of royalties, to install this software to compatible platforms that are able to provide multiple services in the residential, automobile, and industrialist, markets.

The OSGi specification has been designed to complement other standards and initiatives, which are related to domotic networks (LonWorks, CEBus, Konnex, HAVi, Jini, HomePNA, HomePlug, HomeRF, etc.) and broadband access networks (cable, DSL, satellite, LMDS, etc.).

In special, OSGi is a collection of API’s (Application Program Interfaces) based on Java which allows the platform services development. These API’s allow the sharing of multiple services between devices, the addition of services under demand without interfering with the operation of the rest, resources and devices management, security, etc.

Based on this framework, a large number of OSGi services have been defined:

• Log	• Configuration management	• IO connector
• Preferences	• Http service (run servlet)	• UPnP exporter
• Jini	• Package, user, wire and permission admin	• Signed bundles
• Start level	• Application tracking	• Declarative services
• XML parsing	• Power and device management	• Security policies
• Device access	• Diagnostic/monitoring	• Framework layering

4.4.2 Centralized Control System

A centralized control system collects the data from the sensors. This received information will be processed to generate the commands that the actuators will execute [4.30].

Customarily, different control systems have been used to manage illumination, security, heating, air conditioning, power use, electric household, etc. Nowadays, the trend is to integrate all these functions in a common system, with the purpose of reducing the amount of equipment in the building.

This integration process can lead to the situation in which the residential gateway and the centralized control system become the same element. However, at present this is not the case. The gateway, depending on the manufacturer, supports a limited group of centralized control systems together with its corresponding sensors and actuators.

Communication between centralized control system and the rest of system elements is implemented with the control of domotics network protocols (X-10, EIB, LonWorks, etc.).

4.4.2.1 Types of control architecture

Domotic architecture can be centralized or distributed. The classification can be considered from topographical point of view (wiring scheme and physical distribution of devices) or from logical point of view (communication distribution among devices) [4.31]:

- Centralized architecture. This physical architecture is often star network topology. The central control unit is in the star's centre, where the different sensors and actuators are connected to. This topology is logically also centralized.

- Distributed architecture. From physical point of view this architecture occurs, when the network topology is a bus to which all devices are connected. In this case the logical architecture can be centralized or distributed.

4.4.2.2 User interfaces

Centralized control system offers several interfaces for users to connect, to control and to program homes' device. These interfaces are more commonly related to the centralized control system due to these systems larger extension, but they are the basically the same for gateways [4.32].

Until recently few alternatives to interact with the domotic systems existed. The systems could be operated mainly from locally through an embedded keyboard and display screen [4.33]. However there are more alternatives today.

- **Local Interface**. The operator interface usually consists of a screen and a keyboard. Generally the interface is very basic, text commands, due to poor resolution and small screen size. Graphic PC software is other alternative to easier programming.

- **Interface voice**. A much used form of remote control has been the telephone. The user, whose number has been configured into the system, is informed of incidences and alarms by means of stored phrases and words. In order to send commands to the system the user uses the phone keyboard. In the future, when natural speech systems have better quality and lower price, it will be possible to engage in a dialog with natural language with the system.

- **Mobile messages interface**. In order to avoid sabotages in the fixed telephone lines centralized systems also incorporate connection with cellular networks. For it, it is necessary to introduce a SIM (Subscriber Identity Module) GSM card within the terminal.

- **Web Interface**. Web interfaces is the most versatile user interface. The centralized control system or a gateway computer must have a Web server, which allows access through intuitive graphical displays to all system, configuration data and to the present state of the system.

4.4.3 Sensors

Sensors collect information from the process (room temperature, water leaks, light intensity, etc.) and this data is passed to the control system which will act accordingly. Sometimes the sensors can communicate directly with the actuators with no need to pass through the centralized control system [4.34].

Some sensors are battery operated, with 2 to 5 years of operating time before a battery change. Battery operation increases installation flexibility, because cables need not to be installed. A great variety of sensors and detectors used for the building automatization exist [4.35]. Next more commonly used sensors are briefly explained:

- ***The atmosphere thermometer***. It measures the mean temperature. The measurement is used for temperature control of room by the heating system/ air conditioning system.

- ***The gas detector***. It is used for the detection of possible gas leaks, avoiding therefore the poisoning of the building users or to reduce the explosion possibility.

- ***The smoke detector***. The detectors of smoke and heat are used for detection of fire start ups. The most used fire detector is the smoke detector, either of ionic or optician type. The detect fire before the temperature rises.

- ***The moisture sensor***. It is destined to detect possible water leaks, thus avoiding floods that damage fitted carpet, park, platform, carpets, or even to drench to the neighbour of down. Generally their location will be kitchens and baths.

- ***The presence sensor***. These sensors are used as intrusion detectors and to automate functions like illumination. The intrusion detectors can be volumetric for the detection of movement, or of perimeter for the detection of breakage or struggle of access door or window. The ideal is to have a combination of both systems, although the volumetric ones can be a problem in houses with pets.

4.4.4 Actuators

The actuators are the element that gateways and centralized control systems use to modify the state of certain equipment or facilities. Actuators are frequently used as mechanisms to introduce motion, or to clamp an object so as to prevent motion. Between more commonly used they are the relays of DIN track, relays for plug base, electro-valves of provision cut (gas and waters), the valves for the heating by hot water distribution, and sirens or buzzers elements for the current warnings [4.36].

For example, when the smoke sensor detects a fire the system will produce an alarm and initiate a telephone call to the user. Also it will close the gas passage to the house, thus avoiding a gas explosion. Actuators and sensors sometimes are integrated in a same device, although this is not very common.

4.4.5 Intelligent Electrical Household Appliances

Common electrical household appliances facilitate daily tasks, thus increasing our leisure time. The new generation of electrical household appliances (refrigerating, washing, furnaces, microwaves, dryers, etc.) are not only home furniture [4.37]. They features different them of available in the commerce at the present.

These electrical household appliances will be interconnected through the control network. They can interchange information and communicate with each others. They can be programmed and controlled through the telephone or the Internet.

The central home can be incorporated to a refrigerator or specify centralized control system. The refrigerator is the electrical household appliance more appropriate to do this function, because their ample doors allow embedding the needs hardware.

In the future these intelligent household appliances can perform many tasks, such as do shopping without leaving house, to consulting a recipe in a data base and to make an inventory of the existing provisions and their use-by-dates.

4.4.6 Intelligent Consumer Electronics

While the electrical facilitates usually help in daily tasks, the consumer electronic devices are dedicated to leisure and entertainment. For that reason these devices usually are located in living rooms, whereas the electric households usually are in the kitchen.

The digital technology in the consumer electronic devices makes able to communicate with each other to interchange information (videos, photos, music, agendas, etc.). Many of them even allow access to Internet services [4.38].

4.4.6.1 Intelligent electronic devices types

The central home electronic devices of the new digital age are the following:

- Digital television. After 50 years as the best transmission mean of TV analogical NTSC (National Television Standards Committee) and PAL (Phase Alternating Line) systems are getting out dated. The quality of image and sound of the terrestrial digital television is far beyond the quality analogical TV.

- Mobile phone. The enormous mobile telephones of the 1980's have become tiny devices of attractive design with high resolution displays and manageable keyboards. They are pocket computers and more.

- Personal Digital Assistant (PDA). The personal assistance is a small terminal device that resembles a small size laptop. In addition they have good computer applications, greater tactile displays with hand writing recognition systems.

- Web Pad. It is basically a tactile high resolution colour display user interface device that allows the Internet access. Their main applications usually are electronic mail, Web contents and Internet access

- Home Cinema, also known as Home Theatre, improve the quality of audio-visual systems. They comprise of several devices and system like video projective, radio and TV receivers, DVD players and recorders, game consoles, cinema screens, light control systems and more.

- Digital Video Recorder. DVR, also known as PVR (Personal Video Recorder), replaces the VHS tape recorders. It produces better quality and it is fully digital.

- Web Camera. These are very small cameras with a not very high quality. These cameras contain an own Web server that allows the users to assign to each camera a unique IP address. Video-monitoring, tele-attendance, tele-education, video-conference...services take a great importance in the domotic scope.

- Video Game Console. These are devices for playing video games. The presents offer the connecting themselves to Internet possibility, although this connection is still oriented to the games in network.

4.4.6.2 Digital Living Network Alliance

Some groupings among companies with working in the standards and open protocols promotion purpose have arisen. These objectives try to take care of the lack of existing compatibility at the moment between different devices in intelligent home. "Digital Living Network Alliance (DLNA) was created in 2003 by a few of companies. Nowadays more than 250 companies comprise DLNA including consumer electronics, computer and mobile device manufacturers" [4.39].

Users every time accumulate more digital containing through digital devices. The traditional equipment for digital contents storage and the equipment connection are very complex and require long time and efforts. The final goal is to simplify the content interchange among different apparatuses from the modern home.

The main effort will approach in details of IP communication protocol, Plug and Play configuration protocol, and WiFi communication technology implementation. Other groups like UPnP (universal plug and play) Forum are taking even more DLNA importance [4.40].

4.5 Applications

Some domotic application examples have been already mentioned in the project. Most of imaginable technological uses in the home environment compound domotic applications. They will take charge of greater number of task more and more [4.41]. Some domotic application examples can be contemplated in Figure 4.5:

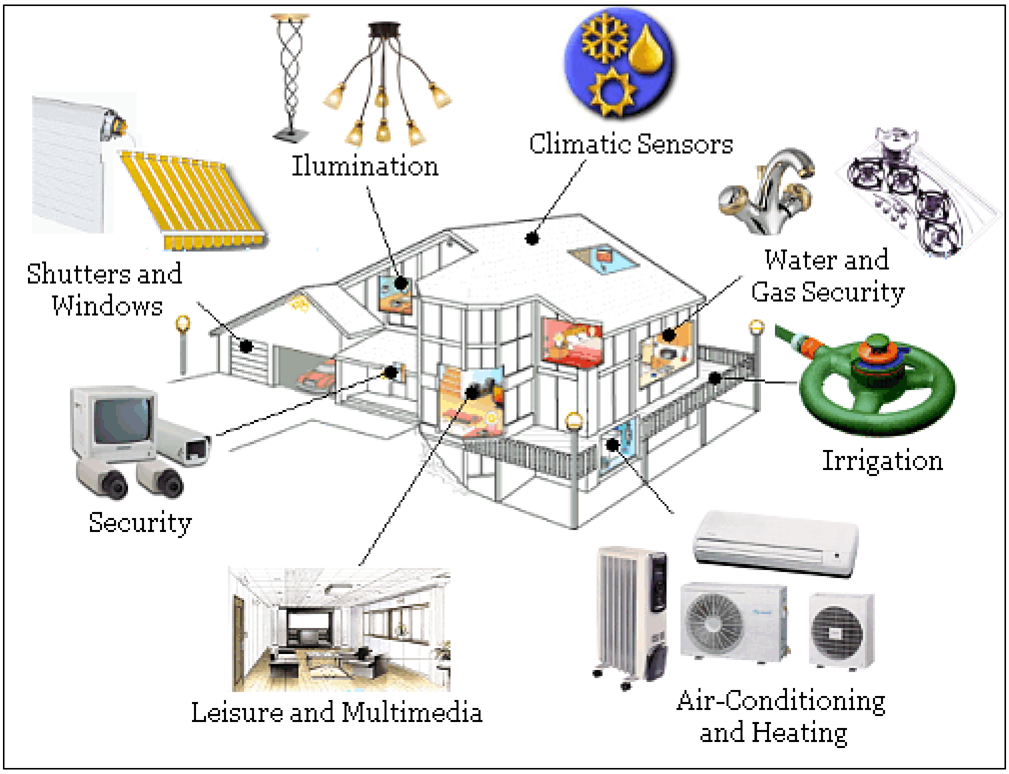


Figure 4.4 Domotic home and the main function and automated tasks

The applications that are of interest to the end users can be divided into several categories or functional areas [4.42]:

- Security.
    - Security and surveillance systems (tele-security, tele-attendance, etc.).
    - Alarms (fire, smoke, service failure, safety, etc.).
    - Access control systems (lock and unlock conventional hinged doors).
    - Monitor motion and movement inside and outside the home.
    - Call specific people in case of certain conditions.
    - Water, plumbing and gas security (to avoid floods and explosions)

- Comfort.
    - Remind to take medications.
    - Act as an alarm clock.
    - Help with the shopping list.
    - Illumination. Switch on or off light and lamps.
    - Central vacuum systems.
    - Pet care (temporized dispenser).
    - Plant care and watering.
    - Specifics assistive appliances (speech recognition software).
    - Automated furniture (auto-washing systems after use).
    - Storage inventory systems (fridge).

- Energy saving.
    - Alternative energy system control and monitoring.
    - HVAC system (manage temperature in house housing thermostats, climatic sensors, and heaters)
    - Intelligent electrical appliances (turning off when they understand the task has finished).
    - Open or close curtains, blinds, and awnings.

- Communications.
    - Answer the phone or control answering machine.
    - Retrieve weather or news headlines using internet connection.
    - Use speech systems for dictation.
    - Internet broadband connection.
    - Videoconference.
    - Local area networking.
    - Telephony services.

- Entertainment.
    - Video and audio systems (TV, home cinema, video games, projectors and screens, acoustical treatments, multi room systems …)
    - Consumer electronic device.
    - Automatic scenes for dinners and parties (special light levels and adequate music).
    - Web cameras (also for security).

Chapter 5

Home Networking

Domotic communication network is taking more and more importance and correct data transfer is the key for those Domotics systems.
In this section, the main domotic communication features are explained including the different network types.

5.1 HAN, the Home Network

Most houses will have soon two twisted inner telecommunication networks, one for telephony and other of data distribution .ICT's rules regulate the unfolding form of these networks in houses guaranteeing telecommunication service provision independently of the contracted operator.

Main communication networks already had been briefly described and classified, during chapter 3, attending to their extension area. In Domotic case, a special network type is considered, HAN (Home Area Network).

"A HAN is a network within a user's home that connects a person's digital devices, multiple computers and their peripheral devices to telephones, VCRs, TVs, video games, home security systems, smart appliances, fax machines and other digital devices that are wired into the network" [5.1].

In order to get that all domotic devices, discussed in chapter 4, to work together, it is necessary to connect them to an internal network, which is generally known as HAN. HAN is a home LAN. These wired or wireless networks usually are divided in three types of networks, depending of devices that are going to interconnect and on the applications that are going to offer: domotic network (also known as control networks), data network, and multimedia network, showed in Figure 5.1.

"In general, HAN networks represent local communication systems that connect devices with certain hardware and software. This allows transferring data at a certain speed, in short distances, and within a private location" [5.1]. Generally, HANs only have two physical networks, one for the data and multimedia networks, and other one for domotic network. The device intercommunication protocols are different for those networks, although it is possible that in future they end up converging around TCP/IP.

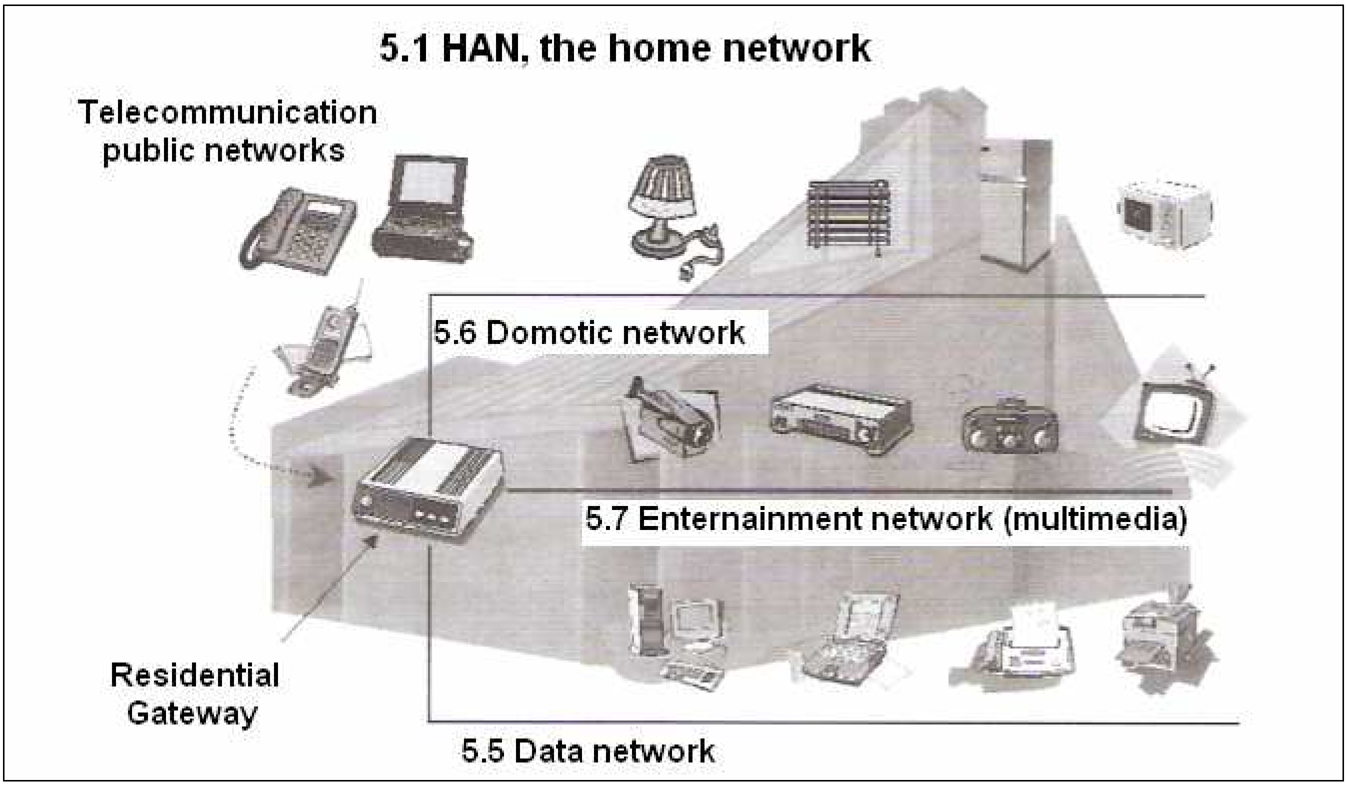


Figure 5.1 A HAN structure, composed by different networks type in an intelligent home example [5.2]

Connection from HAN network to outside world is needed and this is carried out using public telecommunication networks.

5.2 TCP/IP

"This communications protocol was developed under contract from the U.S. Department of Defence to internet-connect dissimilar systems. TCP/IP is the standard communications protocol of the Internet and most internal networks. Ethernet is the local network standard. TCP/IP is responsible for routing packets and ensuring that everything sent was received. Ethernet is an access method that is responsible for moving packets from one node to another" [5.3].

"The IP suite provides two transport methods. TCP ensures that data arrive intact and complete, while UDP just sends out packets. TCP is used for everything that must arrive in perfect form, and UDP is used for streaming media, such as VoIP and videoconferencing, where there is no time to retransmit erroneous or dropped packets in real-time" [5.3].

TCP/IP is a routable protocol, and the IP network layer in TCP/IP provides this capability. "The header prefixed to an IP packet contains not only source and destination addresses of the hosts, but source and destination addresses of the networks they reside in. "Data transmitted using TCP/IP can be sent to multiple networks within an organization or around the globe via the Internet, the world's largest TCP/IP network" [5.3].

Every node in this kind of network requires an IP address which is either permanently assigned or dynamically assigned at start-up.

5.3 OSI model

Normalization plays a preponderant role due to the heterogeneity devices interconnection and communication network necessities. This is the reason of the necessity to base the network operation in the reference model Open System Interconnection, more known as OSI model.

“All OSI (Open Systems Interconnection) communications software implements global standards that are developed by the ISO (International Organization for Standardization). An OSI standard specifies a protocol or defines a service for one functional layer of the OSI reference model” [5.4].

“The OSI reference model is a hierarchical architecture of seven layers for data exchange between systems with incompatible operating systems. The architecture provides standard protocols, services, and interfaces so systems that implement these standards can communicate” [5.4].

“The definition of a common technical language has been a major catalyst to the standardization of communications protocols and the functions of a protocol layer” [5.4].Table 5.1 lists the functions of the OSI layers.

Layer	Name	Responsibilities
Upper Layers		
7	Application	Provides for distributed processing and access; contains the application programs and supporting protocols (including File Transfer, Access, and Management (FTAM) and the Association Control Service Element (ACSE)).
6	Presentation	Coordinates the conversion of data and data formats to meet the needs of the individual application processes.
5	Session	Organizes and structures the interactions between pairs of communicating application processes.
Lower Layers		
4	Transport	Provides reliable, transparent transfer of data between end systems, with error recovery and flow control.
3	Network	Permits communications between network entities in open system on a sub-network, intermediate systems, or both.
2	Data Link	Specifies the technique for moving data along network links between defined points on the network, and how to detect and correct errors in the Physical layer.
1	Physical	Connects systems to the physical communications media.

Table 5.1 Layers of the OSI Reference Model and their functions [5.4]

5.4 Basic concepts for internal networks

Habitually HAN will have to be supported by a wiring system that provides the physic mean for different equipment interconnection. This wiring system must be sufficiently flexible “to adapt the continuous evolution of the used technologies and requirements which there are to fulfil” [5.4].

5.4.1 Wiring Structured Systems

As answer to this flexibility necessity, it is advisable to equip buildings with a pre-wiring system correctly designed and installed. This pre-wiring system could be formed by different cable technologies, and even by wireless mean, in order to satisfy present and future interconnection necessities with smaller possible cost.

Structure of wiring system in a data network within a building is integrated by different parts [5.5]:

- Sometimes, but not always, of a ***telecommunication cabinet*** or ***box***, where in ordered way concentrators and patch panels are placed.
- ***Servers*** where available information by the users (printing, remote access….) is placed.
- ***Concentrators*** or ***hubs***, that makes the signal amplifier function and to which nodes are connected. Usually they are connected to the vertical network wiring.
- ***Patch panels*** are cables organizer, with its inputs and outputs. These distribution panels are located in specific rooms, commonly denominated wiring closet.
- ***Patch cords*** are UTP type cables, which interconnect the patch panel with the concentrator, as well as to the user socket with each one of the terminals.
- ***Horizontal wiring*** is extended from work area to communication room. Usually it uses UTP cable and links the patch panel with each one of equipment sockets.
- ***Vertical wiring*** or ***backbone*** is used if the network is distributed by several floors. Generally high capacity wiring is used, so information from several equipments (to horizontal wiring connected) must to be collected.

5.4.2 Wiring normative, categories, sorts, and topologies

“System of structured wiring is a set of cables and connectors, its components, design and installation techniques. Due to this, it will have to fulfil norms in order to give service to any kind of local data network, voice and other communication systems, without the necessity to resort to only one equipment and program supplier” [5.6].

The most complete norms on wiring are described ones by ANSI/EIA/TIA (American National Standards Institute/ Electronic Industries Alliance/ Telecommunications Industry Association) in EEUU [5.7], and ISO/IEC (International Standards Organization/ International Electro-technical Commission) in Europe [5.8].
Electrical and Electronic Engineer Institute (IEEE) has developed a standard set (IEEE 802.X). These standards had been internationally recognized, and adopted by ISO in its equivalent set ISO 8802.X [5.9].

Systems, consisting generally of a wiring that distributes signals among all connected devices, constitute a HAN physically. "The physic mean shows intrinsic characteristics, that determines the terminal speed at which information can circulate, maximum equipment number that can be connected, and maximum distance to which they can be, among others" [5.10]. Four main different HAN's topologies exist, and some variants of them.

- ***Bus***. "Bidirectional communication way with ending points clearly defined. When one–equipment transmits, signal is propagated to both emitter sides towards all bus connected equipments up to arriving at the ending points from itself" [5.10].

- ***Ring***. "All the equipment is located in a closed curl that forms a ring constituted by a point to point connections series between different equipment from the network. Information runs in a unique direction" [5.10]. Each equipment is an active element in information propagation.

- ***Star***. "This topology is characterized to have all its nodes connected to a central controller or hub. All the transactions happen through controller, being the one in charge to manage and control all the communications". [5.10].

- ***Mesh***. "It is a little habitual topology in the HAN's, but that presents the advantage to have very great robustness before cable cuts or equipment failures. The network equipments are united to each other forming a structure in which two possible routes by each equipment exists at least" [5.10].

Figure 5.2 shows mentioned network topology types as well as other less habitual in HAN's (Line, tree, and fully connected topologies).

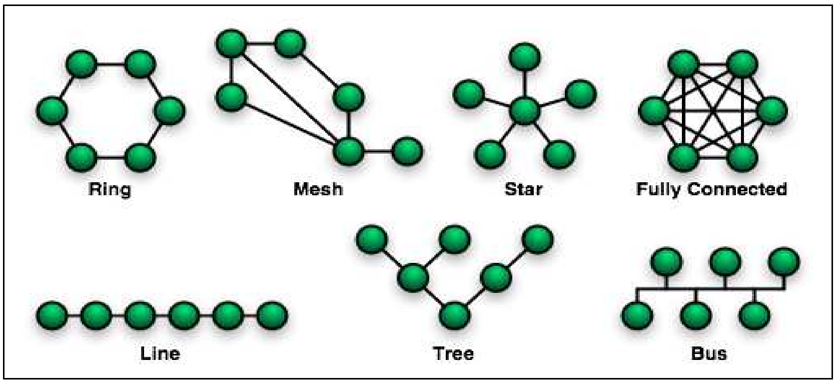


Figure 5.2 Common network topologies in Home Area Networks

5.4.3 Channel access method

In telecommunications, a channel access method or multiple access method allows several terminals connected to the same physical medium to transmit over it and to share its capacity. "A procedure will have to settle down to be able to communicate without interference with other transmitting simultaneously" [5.11]. There are three basic procedures to share a physics means when the connection is direct:

- Selection. “The equipment is warned by an access controller means when arriving its turn, and takes the mean control until pending messages transmission finalizes. Equipment is selected in turn and does not know when they are again going to be it” [5.11].
- Contention. These are based random access methods. “When equipments needs a transmission mean, tries to take it, establishing a contention or dispute with other equipments which also want use it. In these techniques there are usually collisions” [5.11].
- Reservation. “In these techniques, equipment knows with advance when it is going to be able to use the resource. There are not collisions in reservation interval but these are possible in request process” [5.11].

5.5 Data Network

“Internet and the mobile telephony are changing the way in which people communicate and use their computers, mobile terminals, and other electronic devices”. More and more users need tools that allow them to exchange and to transfer information from equipment to others, at any time and in any place, in their work places, their leisure places, and obviously in their habitual residence also. “Therefore the laying of networks which facilitate the information flow is required” [5.12].

In home communication network, traditionally telephony network exists, but it must evolutes towards a data network in order to adapt to the new users necessities (more and more centred in electronic archives, images, voice over IP, etc.).

Next available technologies more adequate to create local data networks that allow great information volume exchange between any devices are indicated in table 5.2, making special emphasis in the most important technology, Ethernet.

“Certain chaos in the residential data networks scope exists. Whereas in the companies world, Ethernet 10/100Base-T is the unquestionable market’s leader in its different categories, in the house world there are different technologies that compete finding a specific segment that to take care of” [5.12].

Attending to network installation necessities and network area extension the selection range is reduced. Table 5.2 shows the best solutions according to the available cable type.

New cables	Existing cables	Wireless
• Ethernet • USB • FireWire	• HomePNA • HomePlug	• Bluetooth • HomeRF • WiFi

Table 5.2 Most adequate networks according to available cable type [5.12]

5.5.1 Ethernet

“Ethernet is a large, diverse family of frame-based computer networking technologies for LANs. Ethernet is a network standard of communication using either coaxial or twisted pair cable” [5.13]. An Ethernet socket can be observed in figure 5.3.

“Ethernet is a branching broadcast communication system for carrying digital packets among locally distributed computing stations. Frames are the format of data packet on the wire (table 5.3). Ethernet is defined by the IEEE as the 802.3 standard” [5.14]. It was originally based on the idea of computers communicating over a shared coaxial cable acting as a broadcast transmission medium.

Figure 5.3 Ethernet socket

“From this early and comparatively simple concept Ethernet evolved into the complex networking technology that today powers the vast majority of local computer networks” [5.15].

Ethernet is wired in a star configuration with a hub or switch in the middle. “Hubs, which predated switches, are shared media device. All stations attached to the hub share the total bandwidth. Switches provide each sender and receiver pair with the full bandwidth and are significantly faster than hubs. Like the client machines, Ethernet switches and hubs also support 10/100 and 10/100/1000 speeds” [5.16].

Preamble	Destination address	Source address	Length/ ethertype	Data	FCS
8 bytes	6 bytes	6 bytes	2 bytes	Variable 46-1500 bytes	4 bytes

Table 5.3 Ethernet frame

5.6 Control Network

Device control networks or domotic networks are used for automating and controlling applications in intelligent buildings independently of data and multimedia networks. Domotic network handles sensors and actuators which allow the building automatization. Domotic network does not have forts bandwidth requirements for its operation due to mentioned elements features. In many cases also some easy intelligent electric households consist this network [5.17].

Domotic network usually is centralized. This centralized control system is necessary to communicate devices with others, because it tries to reduce the complexity and size of sensors and actuators, being necessary a device that concentrates the most system intelligence part and allows the users interact from it with all the installation. This centralized architecture reduces the system robustness, because if the “electronic brains” fails, the rest of devices will not be able to work [5.17].

Central control system communicates with sensors and actuators distributed by all the building, using the same commands language or protocol. Protocol specification usually includes the possible physical means which it has to use. The most used means are twisted pair cable, low tension mains and radiofrequency wireless.

It is advantageous if a protocol is supporting several physical means, with the purpose of being able to adapt in a more flexible way to the particular building topology and to take advantage of the things each one can offer.

The department twisted pair network used in this project, “Linet Network”, and its peculiarities will be commented in appendix B. It is clear example of Domotic network.

5.6.1 Domotic Protocols

Nowadays a great number of domotic devices control protocols co-exists. They are designed to cover specific areas or concrete needs. This has made the integration work difficult. The mixture of different trade brands in a same installation requires much experience by the installers, engineers and users. The technologies that only cover a concrete market have less possibilities of surviving than other with higher sights. In our days flexible and open solutions are prevailing [5.18].

These protocols always cover at least the following OSI levels: physical, data link, network, and application. The application layer defines the possible commands and answers to these commands sets, which will allow the making of the typical control and supervision functions. The ideal thing is that all levels would be implemented in the protocol offering the manufacturers the possibility to use them or not depending on the system type.

Most of the control protocols have been specially designed to be embedded to the minimum possible cost in small devices. Frames were designed as simple as be possible.

However TCP/IP protocol was designed to transfer great amount of information, mainly between distant computers. Network layer protocol at the moment in Internet (IPv4) is of 20 octets. In IPv6 the header has a fixed size of 40 octets.

The cost of electronic hardware has been reduced drastically during the past few years. The Domotic network is not only formed by sensors and actuators together with the centralized control system, but also household electric and more complex electronic devices form part of it. These networks provide enough bandwidth to be shared by diverse devices and applications. Automatic configuration techniques (Plug and Play) adoption is also a world-wide tendency, like it happens in computer science sector, becoming the ideal tool to assure the equipment interconnectivity in anywhere of the world and over any network type.

For this reason, the future will go probably not only towards current control protocols convergence, but also towards the use of TCP/IP protocol as part of these protocols. As consequence, “the only level that will be necessary to specify will be the application layer”. In this application level also protocols will use Plug and Play techniques in order to get automatic devices configuration with the smallest possible user intervention [5.19].

Next, main characteristics of the most important existing control protocols in the market are described. Also the evolution and standardization adopted depending on the geographic area will be commented.

5.6.2 KNX

“KNX is a standardised (CENELEC norm EN 50090, ISO/IEC 14543), OSI-based network communications protocol for intelligent buildings” [5.20]. This protocol is the successor to, and convergence of, three previous standards: EHS [5.21], BatiBUS [5.22], and EIB [5.23].

“The standard is based on the communications stack of EIB but enlarged with the physical layers, configuration modes and application experience of BatiBUS and EHS”. KNX defines several physical communications media:

- Twisted pair wiring (inherit from BatiBUS and EIB Instabus standards)
- Powerline networking (inherit from EIB and EHS, similar to that used by X-10)
- Radio
- Infrared
- Ethernet (also know as EIBnet/IP or KNXnet/IP)

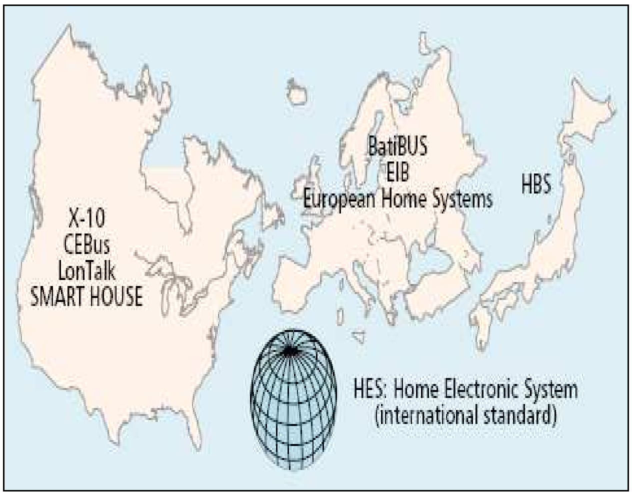
KNX is designed to be independent of any particular hardware platform. “A KNX device network can be controlled by anything from 8-bit microcontroller to a PC, according to the needs of a particular implementation” [5.20].

There are three categories of KNX device, according to the three function modes

- S-mode (System mode). Devices are used in the creation of bespoke building automation systems. S-mode devices have no default behaviour, and must be programmed and installed by specialist technicians.
- E-mode (Easy mode). Devices require basic training to install. Their behaviour is pre-programmed, but has configuration parameters that need to be tailored to the user’s requirements.
- A-mode (Automatic mode). Devices automatically configure themselves, and are intended to be sold to and installed by the end user.

Konnex Association was compound by 9 companies in its beginnings, being it now of more than 100.

Figure 5.4 and 5.5 shows the home systems evolution in the last years, in a map with this technology mainly countries or continents developer.



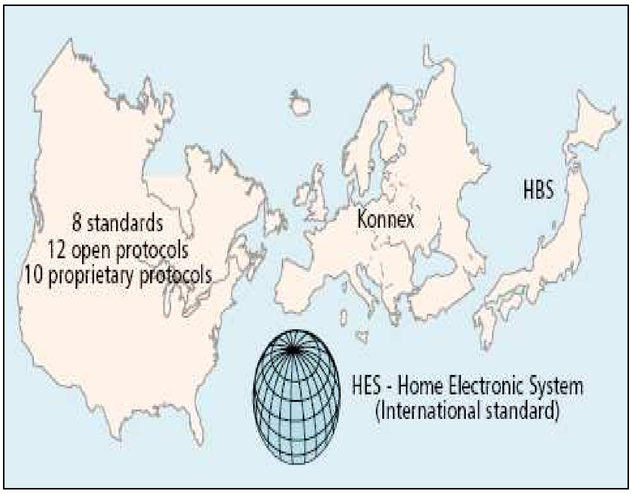


Figure 5.4 Home systems choices in 1997. Figure 5.5 Home systems choices in 2002

5.6.3 BACnet

BACnet is a data communications protocol (for Building Automation and Control NETworks). It is an "ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning), ANSI, and ISO standard protocol". BACnet has been designed specifically to meet the communication needs of building automation and control systems for applications such as heating, ventilating, and air-conditioning control, lighting control, access control, and fire detection systems and their associated equipment [5.24].

The BACnet protocol provides a mechanism by which computerized equipment of arbitrary function may exchange information, regardless of a particular building service it performs. "As a result, the BACnet protocol may be used by head-end computers, general-purpose direct digital controllers, and application specific or unitary controllers with equal effect" [5.24.

5.6.4 HES

The Home Electronic System (HES) is a family of international standards for home systems under development by experts from Asia, Europe, and North America. "The experts are organized into a formal working group that writes the standards and submits them for approval by the member nations" [5.25].

A primary goal of HES is to specify hardware and software that enable a manufacturer to offer one version of a product for connection to a variety of home automation networks. To accomplish this, the working group has published an architecture that specifies the following components for HES:

- Universal Interface. An interface module to be incorporated into an appliance for communicating over a variety of home automation networks.
- HomeGate. A residential gateway to link home control networks with external service provider networks.
- Command Language. A language for appliance-to-appliance communications independent of which network carries the messages.

- Application Interoperability methods and models.

The HES working is also chartered to investigate applications of networks for command, control, and communications in commercial and mixed-use buildings. “Working group together other technology subcommittee are actively engaged in writing standards in the areas: the residential gateway, application interoperability, broadband home network, structured cabling, security, privacy, safety in home networks” [5.26].

5.6.5 Other protocols

More protocols exist, but the mere description of some of them extends to much this section. Most important protocols are enumerated in table 5.4 indicating some of its characteristics of importance.

Protocol	Characteristics
CEBus	• Consumer Electronic Bus • It is the U.S. standard for home systems [5.27]. • In 1984, members of the Electronic Industries Alliance identified a need for standards that include more capability than the “De Facto” home automation standard X-10. The CEBus standard was released in September 1992. • CEBus is a set of electrical standards and communication protocols for electronic devices to transmit commands and data.
X-10	• It primarily uses power line wiring for signalling and control. A radio based transport is also defined [5.28]. • X10 was developed in 1975 by Pico Electronics of Glenrothes, Scotland, in order to allow remote control of home devices and appliances. It was the first domotic technology and remains the most widely available.
SmartHouse	• It was a project of the National Association of Home Builders for as integrated data power network in new homes [5.29].
LonWorks	• It was developed by Echelon and initially marketed for building and factory automation, and then for home automation [5.30]. • It is a networking platform specifically created to address the unique performance, reliability, installation, and maintenance needs of control applications [5.31]. • The platform is built on a low bandwidth protocol created by Echelon Corporation for networking devices over media such as twisted pair, power lines, fibre optics, and RF [5.32].
SCP	• “Simple Control Protocol is an attempt of Microsoft and General Electric to create a control networks protocol that be able to hold fast like the solution in all the building and houses automatization applications” [5.33]. • It tries to put a little order in the existed in UUEE supply. And to support the convergence of all these towards an open and free royalties protocol.

Table 5.4 Other standard protocols for home automation

5.7 Multimedia Network

Multimedia network enables all devices ("brown goods") of the home (CD and DVD players, TVs, Camcorders, HiFi and home cinema, radios…) to get connected. This network is used by the intelligent electronic devices for the information distribution with very strict requirements about information transference volume, quality, and delay.

Main reason to have a multimedia network dedicated to audio and video devices is just the signal of high quality and audio hi-fi exchange. These signals require greater bandwidth than most of home networks can provide.

Next times examples by these networks will be videogames online of pay per view TV diffusion from the codec to all subscriber TVs, photos stored in a digital camera directly sent to a printer, etc.

The electronic devices interconnected to the multimedia network support very different processing capacities and functionalities. Therefore it is necessary that protocols used by the multimedia networks allow abstracting to the users the interconnection configuration details of these devices.

Logic and physical architecture of multimedia network is totally distributed. That is, the whole elements can communicate directly with the rest, although sometimes to have a gateway as interface will be necessary [5.34].

Next, three more relevant architectures in this moment are described. The three ones offer basically same characteristics, but they are supported by different companies. This does not limit its compatibility, because in the three cases mechanisms of coexistence with rest of solutions have been contemplated.

5.7.1 HAVi

HAVi (Home Audio Video interoperability) is a "distributed software architecture which specifies a set of API designed to Interoperability and direct interconnection of video and digital audio consume devices from different types and suppliers" [5.35].

This technology tries to simplify traditional electronic devices installation and handling. HAVi uses IEEE 1394 digital network for commandos and data interchange, which is a standard with large support by computer and consumer electronic industries.

In HAVi network no single controller device exists. Any device is designed to control or to be controlled. HAVi architecture is open, with a scalable implementation's complexity, independent of the platform and the programming language. HAVI architecture had contemplated other building networks integration from the beginning [5.36].

5.7.2 UPnP

"UPnP (Universal Plug and Play) is an extended architecture proposed by Microsoft mainly for all type of electronic devices of different manufacturer's interconnection in peer-to-peer networks". This is an open and distributed architecture based in TCP/IP protocol stack of Internet, that facilitates control and data transfer between connected in home or enterprise networks devices [5.37].

UPnP architecture allows that when network equipment is connected it automatically obtains IP address, announces its name, communicates its functionalities, and learns about other equipment's presence and functionalities in order to make use of them.

Installation is very simple and the network extension or modification very fast. UPnP technology is independent of the physical means, being able to work over the telephone line, mains of low tension, Ethernet, radio waves, and IEEE 1394.

5.7.3 Jini

This architecture provides a simple mechanism so that diverse devices connected to a network can collaborate and share resources with no need of end user network planning and configuration.

Jini also has an automatic discovery procedure so that any device connected to the network is able to offer their resources to others, informing about its processing and memory capacity, in addition to functions that it is able to do.

Jini supports any type of physical means like IEEE 1394, Bluetooth and IrDA. Jini is also independent of the operating system and underlying physical equipment. Jini has been developed by Sun Microsystems. Compatibility and security are guaranteed thanks to Java, and Jini can work in any kind of device [5.38].

5.8 Remote Access Network

When users are outside of intelligent building, it turns out extremely interesting to be able to have access to the same functions and applications that users had when they were inside [5.39].

In order to get users can control remotely the building, as well as to enjoy advanced telecommunications services, it is necessary to connect the building to the public telecommunication network. Thus an interface device is necessary between the internal building networks and public telecommunication networks.

Gateway or centralized control system could be connected to mobile network through GSM, GPRS, or UMTS, for security reasons. This connection protect the system in case of CTN (Commuted telephony network) or ISDN (Integrated services digital network) signal cut, because the gateway voice interface continued being accessible from outside, via radio.

The Internet gateway connection is totally indispensable in order to users enjoy all the intelligent buildings services [5.40]. User will connect through a PC, mobile phone, or PDA to the Web Server gateway program that allows remote control of the home.

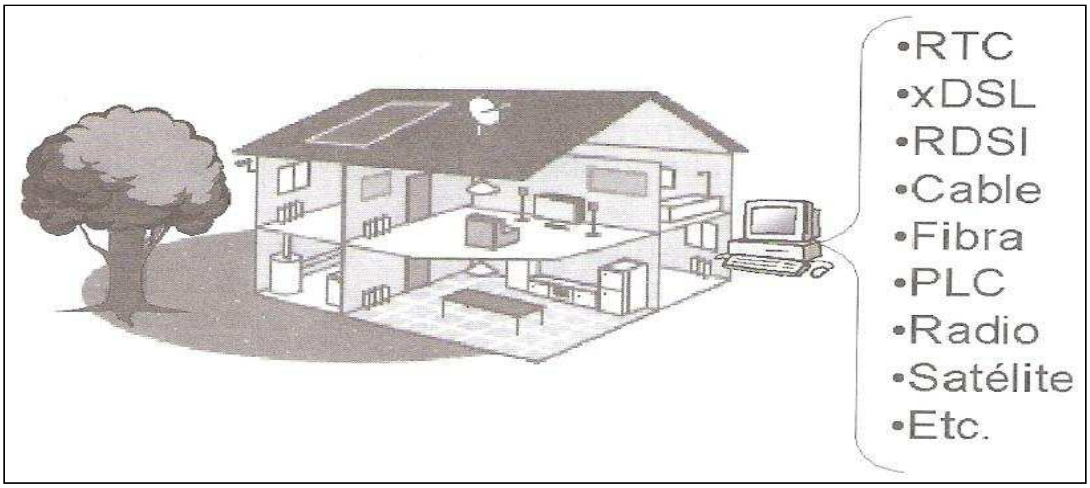


Figure 5.6 Main Internet access technologies from home, where RTC is equivalent to CTN and RDSI to ISDN.

Domotic needs an always-on connection system to the intelligent building. Gateway must integrate or be connected to a device that allows the access to Internet through some of available at the moment broadband technologies. Figure 5.6 shows main home Internet access technologies available at the moment.

Chapter 6

Application

This chapter covers the practical work from the context and main idea of the application until its analysis, including the used tools and an explanatory manual.

6.1 Context and main goals of the work

.
The system consists of a home server software, equipment adapter and a home network.

6.1.1 AVO Project

The application it is a part of a larger project called AVO. AVO acronym means “Open Building Management Server” (in Finish: “Avoin Kiinteistönhallintapavelin”). “AVO project is the result of STOK (“Sähköisen Talotekniikan Osaamis – ja Kehittämiskeskus”, means “Electrical Building Services Center”) and HUT cooperation in the oFMS platform” [6.1].

STOK is a non-profit competence centre for electric building services. It is a part of the city of Porvoo´s organisation. The STOK board, which controls the activities that are carried out at STOK, consists of representatives from public and private sector as well as universities.

This centre develops the oFMS, an “open Facility Management Server”. The oFMS is an open source integration platform, which implements the oBIX interface towards the ICT world and provides a framework for developing equipment drivers.

An integration laboratory is currently being built to support the developments of the oFMS. “The laboratory contains equipment donated by equipment providers supporting STOK’s activities. All equipment is integrated using the oFMS. oFMS provides the oBIX interface to integrated equipment” [6.1].

STOK supports the educational community by developing and providing the oFMS integration platform. In addition, STOK provides courses related to the equipment in the integration laboratory to educational staff.

6.1.2 AVO system specification

The AVO system is a prototype. This prototype is used to show how various devices can be integrated to form a building automation system.

The prototype architecture is depicted in Figure 6.1. This diagram shows the main idea of the application, in which each device is connected to an Equipment Server. Several devices can be connected to one Equipment Server.

The Equipment Server is the link between the devices and the Web Server. The communication between devices is supported through the Equipment Servers. States of the devices are stored within a data base in the Equipment Server. The database is used to control the system directly.

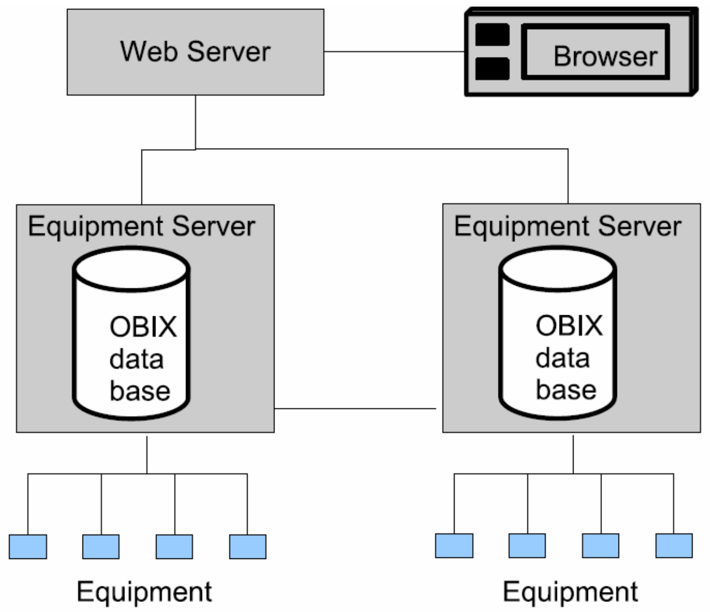


Figure 6.1 Overview of the AVO System architecture [6.2]

The Web Server provides the user interface for Browser. The Web Server is in charge to collect the equipment data from the Equipment Servers. The other way, Web Server sends the Browser request to the Equipment Server to control the devices. Web Server programming is based on oBIX specification as explained in Appendix C.

The software modules of the system are shown in Figure 6.2. The Equipment Server communicates with others servers through SOAP, the protocol for XML-based messages over computer networks. Each Server has a SOAP client and a SOAP server, which send and receive SOAP messages, respectively.

SOAP messages are handled by the SOAP server in the oBIX Web Server. The Web application uses the oBIX Handler to access the equipment data and creates user interfaces for the devices. User agent makes requests to the oBIX Web Server for the user interfaces. The equipment data in the user interfaces is in oBIX format.

When the user wants to control a device, the data flows other way around. User agent sends a request to the Web application. The oBIX Handler sends it forward to the SOAP client, which sends it further as a SOAP message. The SOAP server in the Equipment Server interprets messages and gives it to the Equipment Handler Logic, which stores them to the database and forwards them to the corresponding Equipment Adapter. The adapter controls the actual equipment.

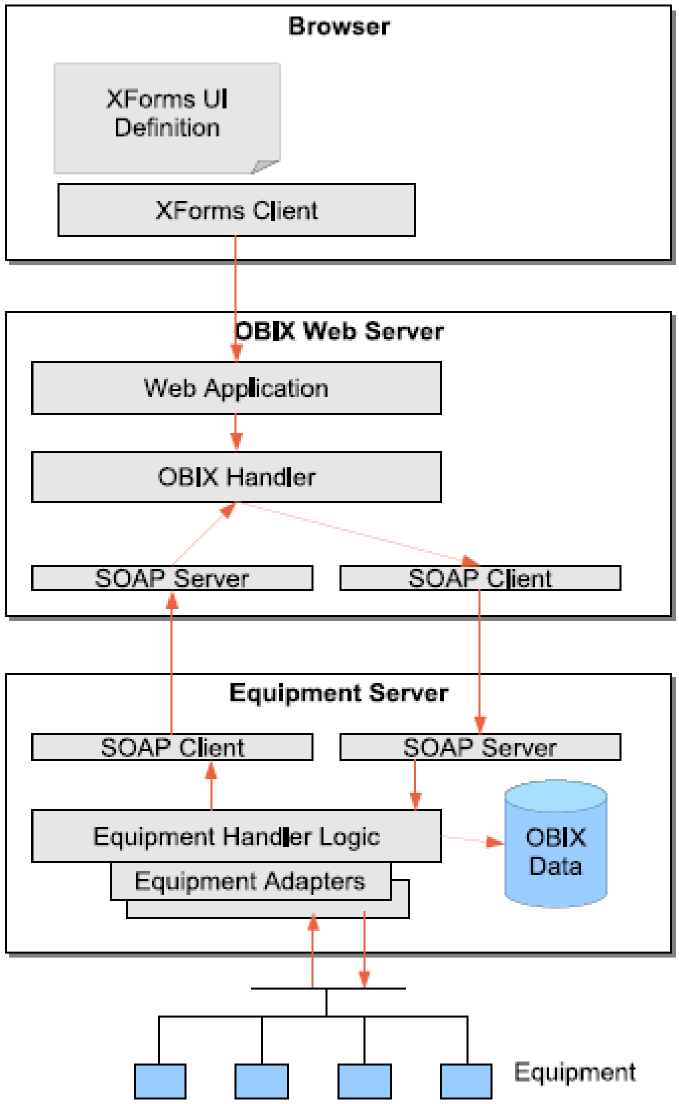


Figure 6.2 Software modules of the system [6.2]

The Equipment Server has interfaces to the devices. The interface is part of the Equipment Handler Logic. Each device has its own adapter, which implements the interface. The Equipment Handler Logic transforms the equipment data to the oBIX formats and stores them to the database.

The Equipment Server consists of four different modules. Its structure is depicted in Figure 6.3. The DataBase module offers a mean to access the oBIX data base by means of DataBase Controller. The networking module handles network communication and directs incoming commands to the Server Logic module.

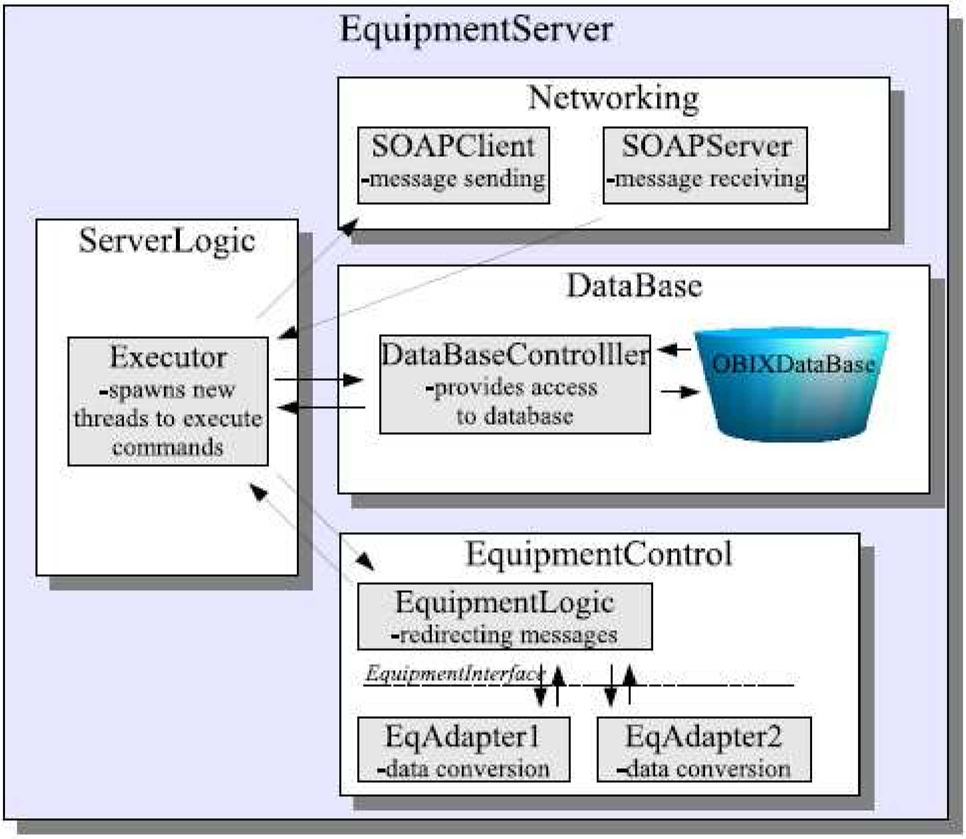


Figure 6.3 Package Structure of the Equipment Server [6.3]

Server Logic module executes commands from other modules by generating a new thread for each command. The use of multithreading is required to implement the system efficiently because the Equipment Server has to be able to execute commands in real time whether they are received from the network or an equipment. Threads using is clearly showed in Figure 6.4.

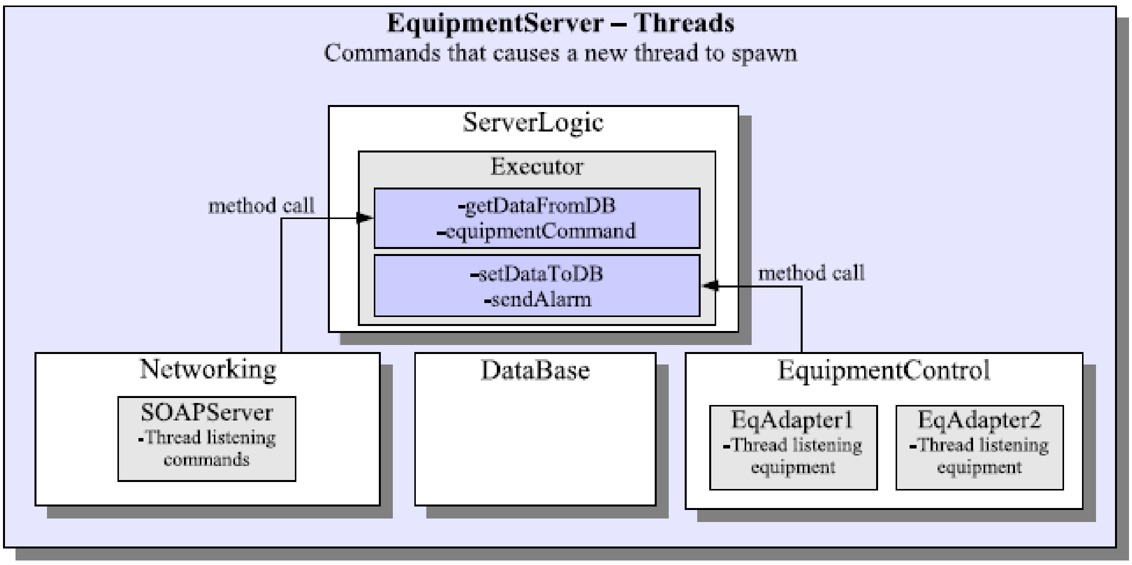


Figure 6.4 Threads in Equipment Server [6.3]

At the first prototype implementation the architecture is simpler than described in Figure 6.3. All the software modules are embedded into a one physical machine. In practice it is an Equipment Server with Web Server, although commands from the user interface (Browser) are transmitted using sockets. This model will be implemented with a singe database which is actually a few regular files for storing the oBIX data.
The connection to the equipment is performed by the Equipment Adapter.

6.1.3 The Equipment Adapter

At first it must to be clarified that the whole project is under development. The term prototype is used for this reason. The design consists of independent program blocks. This design specifies tools and ways to connect these blocks. The Equipment Adapter is part of one of these blocks, the Equipment Server, which is placed in Equipment Control sub-block.

The Equipment Adapter is to adapt different equipment to the system. The connection between Linet network and Equipment Server is done through an Equipment Adapter. Data comes from Linet network, the nodes states is translated with a Java program. This program decodes the Linet UDP data packets.

The main body of the program is based on Linet properties. The data frame for Linet network is the key to develop the way to obtain the network information.

The Equipment Server needs Linet data in oBIX format from the Equipment Adapter. Linet groups' information is fully contained in each of the oBIX Point format.

The Equipment Adapter design let data from other protocol network if the data frame maintains similar as LinetPacket frame. Linet package contains much information within a short message. The information is result of the Linet network analysis and initial nodes data.

The knowledge of nodes´ initial states has great importance because some Points aspects are filled from this information. This previous programming has to be completed before to initiate the application. A boolean value change let to choice if the application have to be based in previous data.

6.2 Used tools

Most important tools used to develop the work of the Master's Thesis application are described in the next sections. They include the software and the hardware used. A normal desktop computer has been used as the system platform.

6.2.1 Linet network

The Linet network was functional in the laboratory before this work started. Only one node has been added to the network during the development of this Master's Thesis. The Linet network is made up of one Linet controller, 9 Linet nodes and twisted pair cable. The Linet controller is of model LIC-04. The twisted pair cable is Category 5 cable. The 9 Linet nodes are of model LN1003.

6.2.1.1 The Linet nodes

The table 6.1 describes the network nodes together with a shorter description of the group function and input and output associated. Third and sixth groups are forming I/O types but have not nodes really. 9th is the new added node, which indicates the alarm value in the application test. Although it is defined as Toggle group, its output lamp turns it into a device quite similar to the Lamp groups.

Node Group	Group Type	Description	Associated I/O
Node 1	I/O	Bathroom 1 Presence Indicator	Input = Presence Sensor Output = Red Lamp
Node 2	I/O	Letter Box with some mail	Input = Presence Sensor Output = Red Lamp
Node 3	I/O	Unknown	-
Node 4	ADState	Temperature in the corridor	Input = Temperature Sensor
Node 5	Delay Timer	Movement in the corridor	Input = Motion Sensor
Node 6	I/O	Unknown	-
Node 7	I/O	Coffee Machine Operation	Input = Heating Button
Node 8	Delay Timer	Countdown since coffee done	Input = Operation Sensor
Node 9	Toggle	Application Test Lamp	Output = Lamp
Node 10	I/O	Bathroom 2 Presence Indicator	Input = Presence Sensor Output = Red Lamp

Table 6.1 Department system nodes summarize.

The nodes location inside the department is showed in Appendix A.

6.2.1.2 Department's Linet Network Controller

The Linet controller is the model LIC-04. It is showed in Figure 6.5. With the actual network configuration the controller is exploiting only the 5% of its capability.

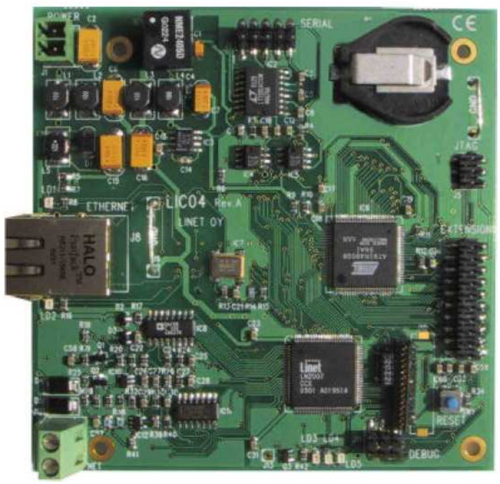


Figure 6.5 Linet controller

6.2.2 Eclipse

Eclipse is the programming tool selected for implementing the system. This tool comes from the Eclipse Open Source Community whose projects are focused on providing extensible development platforms and application frameworks for building software [6.4].

Eclipse is a powerful Integrated Development Environment (IDE) for open source and extensible software. The necessary tools for the developed programming are found in this development environment. The graphic and design tools of Eclipse have been important in this application programming work.

Eclipse was chosen because earlier works on Linet were carried out with Eclipse. Additional reason for choosing Eclipse was the use of Java. Java is an object-oriented programming language developed by James Gosling and colleagues at Sun Microsystems [6.5].

Finally the third reason for Eclipse is the availability of the necessary plug-ins to implement the data communication and to implement the correct frame Point. The way to add the needed libraries and plug-ins became easier by using this tool.

6.2.3 Required Libraries

Two additional libraries were necessary in the program work. Both are free open software and easy to obtain. They are included in the Master's Thesis CD.

- oBIX-0.11.0

  It is the Java software library for implementing oBIX enabled applications. This library is provided by the oBIX toolkit. This toolkit contains a data model for object "obj" trees, XML encoder/decoder, rest session management, and a swing diagnostic tool.

  This 0.11.0 version can be considered a full API. New versions are under development. The 0.12.0 version includes Point Status handled but it fails in other aspects such as incomplete development of Point structure. This is the reason to not use the newest version [6.6].

- J2re 1.4_204

  This is the JRE System Library. It is included automatically in every Java project by Eclipse and contains the standard Java Application Programming Interfaces.

6.3 Blocks and frame program analysis

This section describes the application program structure.

6.3.1 Program Packages

The program is divided to three main packages.

6.3.1.1 Linet Package

The sending and receiving of Linet messages are supported in this sub-section. Only minor modification were made to the original code provided by Linet Company [6.7]. These software libraries for Java contain the UDP communication between a host and a Linet controller over the Internet.

- *Driver.linet.implementation* package is the main package which supports the communication.

A first group of classes is used to transmit data types understood by the Linet Controller. This set contains the *LinetPacket*, *LinetPacketEntry* and *LinetPacketHeader* classes. The *LinetPacket* is a data structure which describes one whole Linet network. *LinetPacket* class contains the other two classes as data sub-structure. The *LinetPacketEntry* class is the data structure which describes a single Linet node. The *LinetPacketHeader* is used to mark a transmission as a request or an answer.

A second set of classes manages the low-level UDP connection. *UDPListener*, *UDPPacket* and *UDPWriter* classes compose this group. *UDPPacket* function is to transmit dates, IP address and source Port. *UDPWriter* function is to write the dates from the *UDPPacket* handled in the Linet Controller using *DatagramPacke*t dates class protocol. All the Linet data packets provide a getRawData returning byte array representing the data structure that will be transmitted through the UDP connection via the write method of this *UDPWriter* class. *UDPListener* works with network info in *FIFO* class buffer and *UDPPacket* read function.

FIFO, First Input First Output, class is the queue entrusted to buffer the data in the communication process. Its synchronized methods allow the correct interpretation of the UDP data.

Some classes were included for other previous worker in this area [6.8]:

- *Driver.linet.event package* contains the *LinetEvent* class and its interface. This throwable class handles the fired of an event when some change in any network node has happened and detected in the analyse method in *LintImpl* class.

- *Driver.linet.exception* package contain two classes *NotOnOffDeviceException* and *NotValueDeviceException* extended from *LinetDeviceException*. Both of them are used to notify about problems in node loading.

Some interfaces have been added to allow better handling and updating of the classes.

- *Driver.linet.service* contains *Linet* and *LinetNode* interfaces. First of them describe the access point to the Linet application. The second declares group types constants and the necessaries methods to control the *LinetPacketEntry* frame class.

6.3.1.2 Adapter.frameCreator Package

This sub-package includes all the components class necessaries to build the whole oBIX point structure by one Linet network.

GroupXMLMaker class is the core of this frame. When *GroupXMLMaker* is created the call to this class unleashes the tidy execution of each class presents in this sub-package. In order to charge the network information, the *LinetPacket* will be given in the constructor method.

This class generates a Java Object with the required conditions by the XML format.

Figure 6.6 shows the token way to develop the *GroupXMLMaker* structure. At first a *HeaderGroupXMLMaker* is created, the frame generated by this class will be the basis Java Object at which the rest will be added. General information about the network status and the equipment is generated here.

The second class loaded is *ListPointsXMLMaker*. This class generates an oBIX List object which will classify the Linet groups above the four kinds of oBIX Points. This classification selects among the correspondent Points creator classes *BoolPoints*, *EnumPoints*, *RealPoints* and *StrPoints*. These classes incorporate specifications for the different group types. All of them are extended from the *Root* class and contained in the *PointTypesMakers* sub-package.

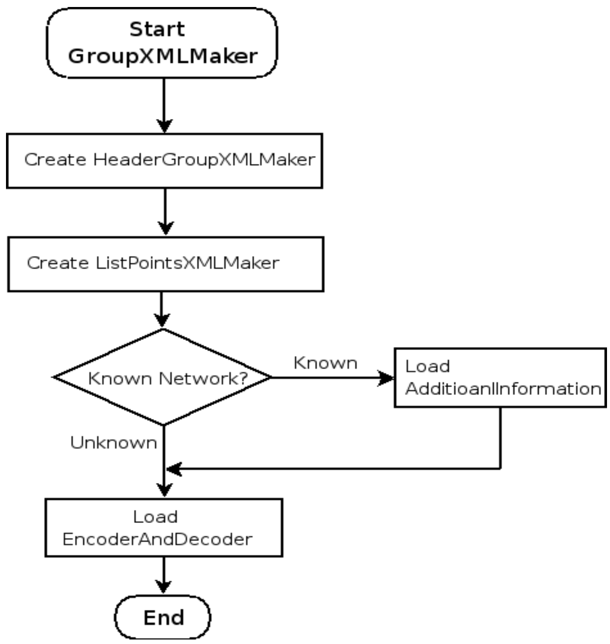


Figure 6.6 GroupXMLMaker function structure way

Root class generates the common structure part in the different points. Root class contains the oBIX Point declaration together with some “set” functions that briefly describes the common properties as Point “Status” or group number in “Name”.

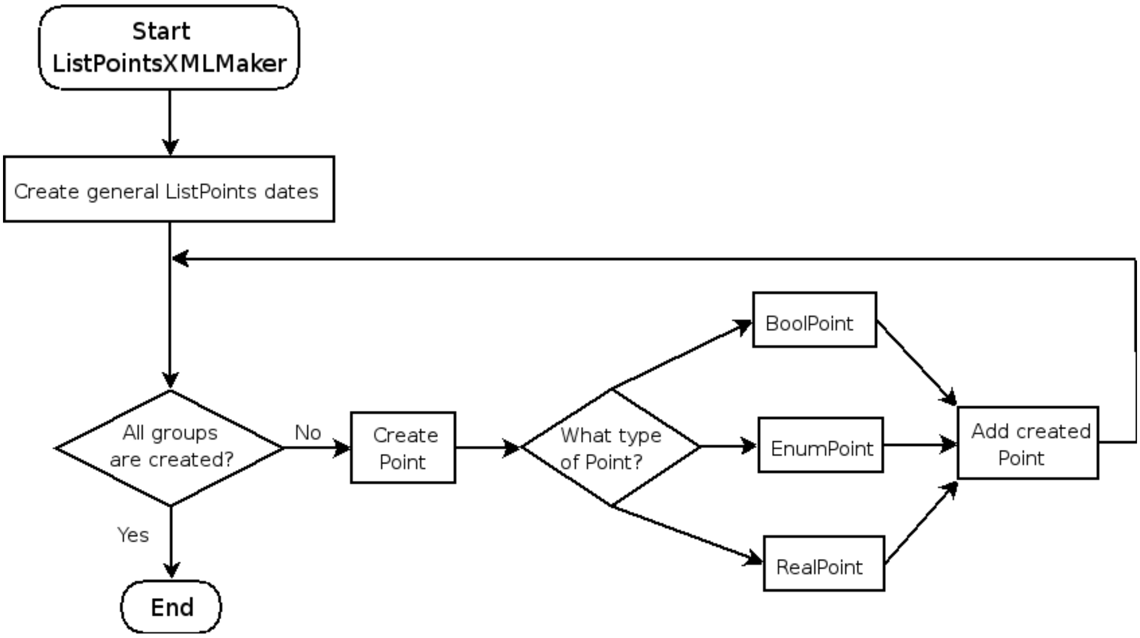


Figure 6.7 ListPointsXMLMakerfunction structure scheme.

The importance of this group resides in the transformation task from Linet group types to oBIX point types. Information mustn’t be lost in this adaptation step. The chosen way is showed in Figure 6.7.

When the entire network group frame is broken up to Points the program thread ask if knowledge about the network is available. In the affirmative case *AdditionalInformationLoader* class will be loaded. The network and devices initial data and information fill these class configuration parameters.

Finally the *EncoderAndDecoder* class is loaded. This class function is to provide a physical format of the information in XML extension file in the specified folder. The file will contain the last value taken from the network just after of the last nodes detected changes.

6.3.1.3 Adapter.interfaces Package

The main Interfaces task is to define a method’s list of its classes. These are action arrays that one object can carry out. This code allows taking out maximum performance of the program abstracting methods to an upper level.

IEquipmentAdapterForGroupsXMLMaker is the *GroupsXMLMaker* interface. This interface contains the bulk of the methods required by the program implementation.

IEquipmentLogic interface is a call to implement methods coming from the Equipment Logic in the other side of the adapter bridge. One call back method is declared in the last interface which loads this *IEquipmentLogic* with a *void* function.

The last interface is *IEquipmentAdapter*. This piece of the whole program had linked with the Telecommunications Software and Multimedia Laboratory program.

This design allows both applications to be built almost without any interaction between them. The key of this interface is its clear way to define methods and the objects given from them. These have to specify what kind of function is used and what is expected from it.

The methods are provided from the Adapter class, where their contents are extended. Most of these methods are defined easily using the *GroupsXMLMaker* interface. They handle the operations to “get” the structure Points from the Adapter frame and to “set” the Linet network sending the same format Points. A set of information functions is defined together with “*status*” handling. Some control methods as *turnOn* and *turnOff* are included too.

6.3.1.4 Adapter.main_control Package

The main control parts are included in this package. The application work guide resides in these three classes. They handle themselves together with the rest of class to execute correctly the adapter.

Nevertheless one of them, the *Executor* class, is not a really necessary class. It contains the code lines to throw the application. These three lines must be included in the Equipment Logic entrusted with the Adapter start.

Other issue of this design is the shield function of this class. This allows the development of the whole GroupXMLMaker and its methods without preoccupations about the connection with the other bridge side, that could be any program which carries out with the specifications and load this mentioned code lines.

The *Adapter* class is the support to develop the required methods by the *EquipmentLogic*. Moreover it has the function of loading the *LinetImpl* class. The Linet Controller assigned IP address has to be given in this load.

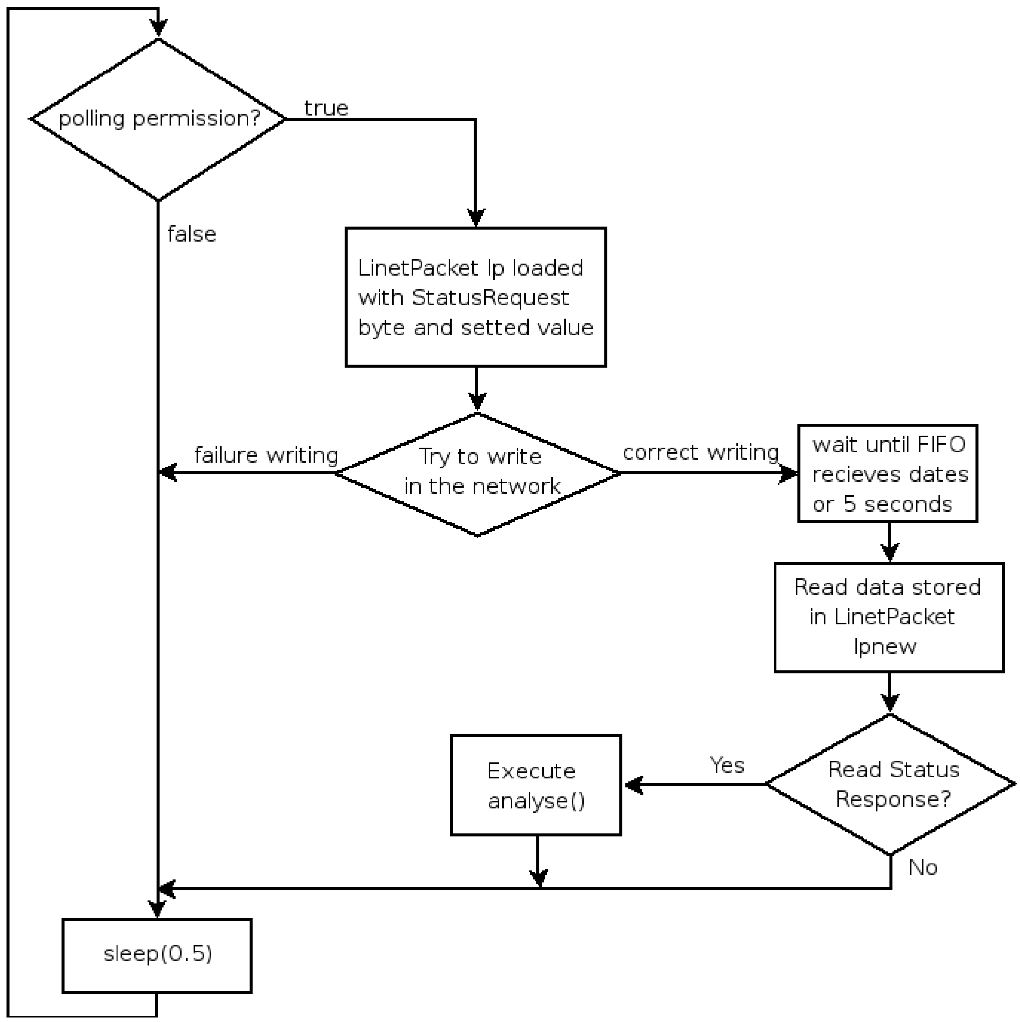


Figure 6.8 LintImpl function way scheme.

With the load of *LinetImpl* class the key process begins. This class is the core of the code and handles the rest of classes in Linet and Adapter packages. The complete work of this class is showed in flowchart Figure 6.8.

The most important method of *LinetImpl* is to *analyse*. The flowchart of how is working this function is in Figure 6.9.

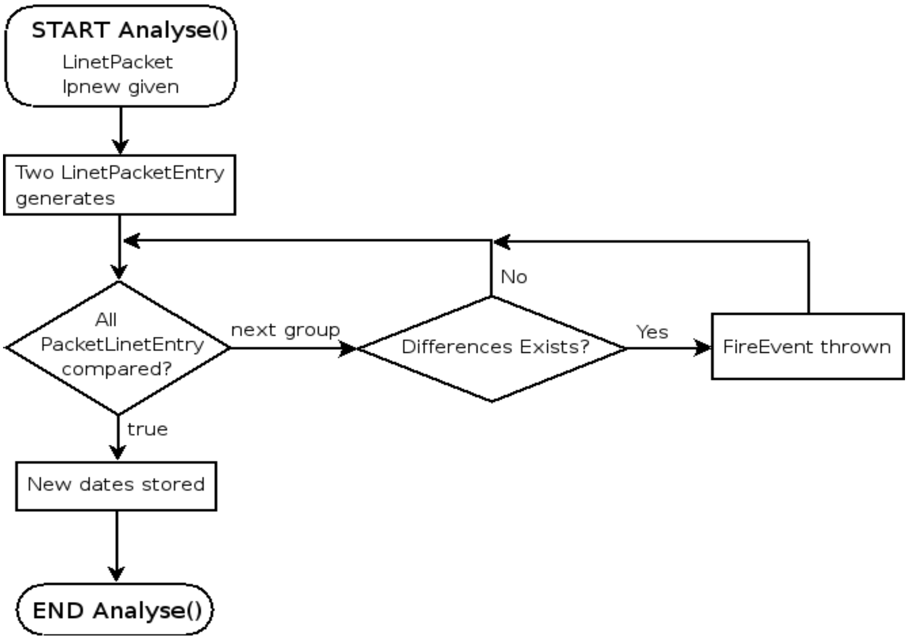


Figure 6.9 Analyse function structure scheme.

6.3.2 Program's global work

The next Figure 6.10 shows the Adapter application execution. The three mentioned code lines are in the Executor way.

Once the *Executor* or the *EquipmentLogic* is thrown together with the Adapter call, the *IEquipmentLogic* declared methods will handle the Adapter.

Controller only transfers data after a request is received. Once the Adapter is working it is necessary to have access to the network information all the time in order to know possible changes. It is necessary to poll the controller in short time periods. This responsibility is given to the LinetImpl class. As long as it is running, this class is polling and continuously writing to the controller. The controller answers with information about variations in the Linet nodes. The method *Analyse* is in charge of the status node changes.

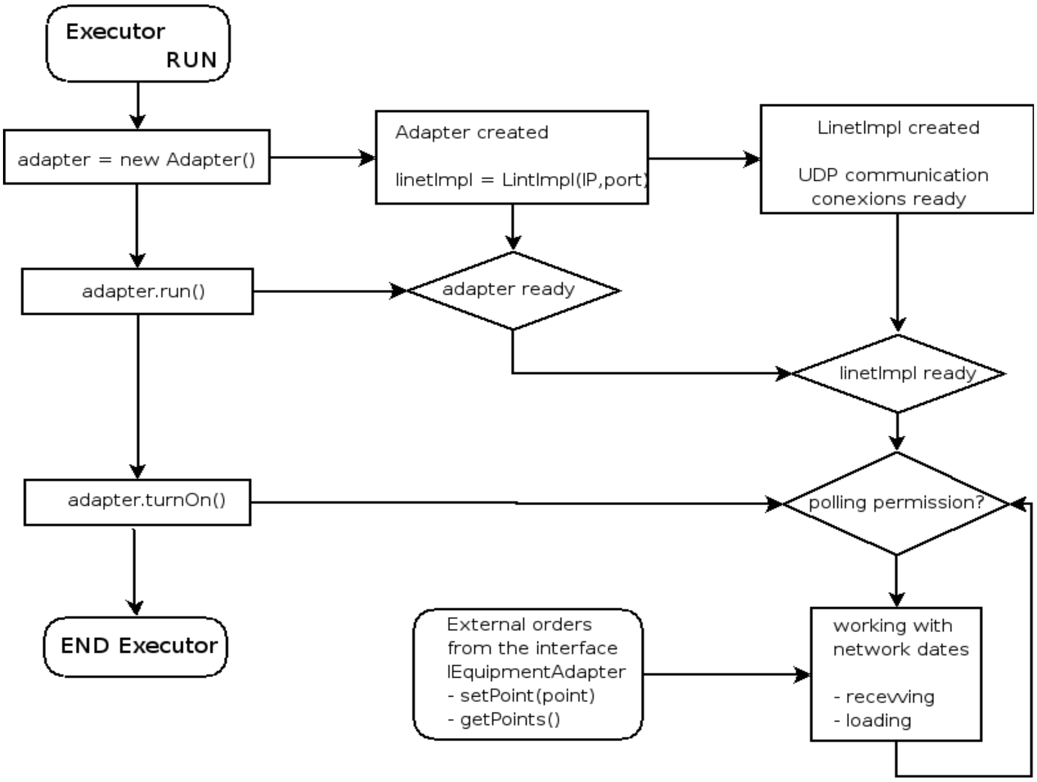


Figure 6.10 Adapter function execution scheme.

When any change appears, an event is fired containing the new node value from *Analyse* function. Some implemented methods in the Linet interface by the *LinetImpl* class provide tools to *addListener*, to register *LinetEventListener* as well as *changeStatus* and other to modify any node of the network.

Program design doesn't divert the threads approach in the EquipmentLogic way. To continue one Adapter is created for each different EquipmentLogic that call it.

The IEquipmentLogic methods are used by EquipmentLogic that generates the Adapter. These methods act directly in the LinetImpl and work with the oBIX structure development and storing continuously in the LinetImpl.

6.4 Manual

This manual section explains briefly some particular aspects of this Master's Thesis application.

6.4.1 Adding device to the equipment

The program recognizes automatically each node added to the Linet network. The nodes are configured with a Linet controller and a test device (forming a little Linet network). The node check-up had to be done from the controller version which will be working in the Linet Controller. Group type and parameter values are easily configured through the Linet instructions [6.9].

If the features of the new device added to the network are known, this information should be added in the *AdditionalInformationLoader* class. A new sub-section will be programmed paying attention to parameters and peculiarities of the new group, its group type and its task.

6.4.2 Extending the program

The information transfer is limited without EquipmentLogic variations. EquipmentLogic changes mean new functions, blocks and program variations in the Adapter.

The oBIX platform status is still under development. This can be noticed by testing the available toolkits. For example, the newest version 0.12 has added some variable handled as *status* object set and get methods, but other functionalities aren't included in this pack as the Point definition and methods.

As new updates will appear new toolkits will change their features and adopt new ways that will be oriented to a easier programming.

If new Linet groups are added the programmer must pay attention about how classify them in *ListPoitnsXMLMaker* among the oBIX type Points. The *StrPoint* type Point work with "string" values in oBIX Point format. This type is disconnected at the moment because there are no Linet groups that use it. The program includes the code able to work with these Point types. The *StrPoints* class in *PointTypesMaker* package contains this code.

The present Linet network is only composed of I/O node, AD/State, Delay Timer and Toggle Linet type groups. Other Linet type groups can be easily programmed. So if a new network with different device types will be connected, the Adapter wouldn't have problems in creating the information frame which contains and operates with them.

Chapter 7

Testing

The application test carried out is explained in this section. The main results will be included as the conclusions

7.1 Test approach

A complete set of tests and practices with methods and different parameter possibilities was done as a general development task during programming. To demonstrate the correct operation other special test has been carried out. The different parts of the global program were developing independently, except by the common link specifications. This test shows that the two different parts work well together.

This test shows the potential of the application when executing it together with other blocks from the AVO demoplan.

The larger limitation of this test has been the uncompleted development of the Web Server application. In fact, Web server application part is still under development.

7.2 Installation requirements

The web server application part required some special tool installations.

- The Web Server Apache Tomcat. It works as web containers and it is developed by the Apache Software Foundation Tomcat [7.1]. Tomcat implements the servlet and the JavaServer Pages(JSP) specifications from Sun Microsystems, providing and environment for Java code to run in cooperation with a web server.

Once installed the start and stop Tomcat Server icons created allows starting of the Web Server application.

- Mozilla Firefox software. It is a free, open source, cross-platform, graphical web browser [7.2]. This navigator is the necessary mean to access to the Web page of the developed Web Server. In our case the URL is in a folder in local host. This is http://localhost:8080/xforms/avo2.

7.3 oFMS

The oFMS acronym means is Open Facility Management Server. It is the Web Server application developed from TML laboratory. Figure7.1 shows the designed visual interface.

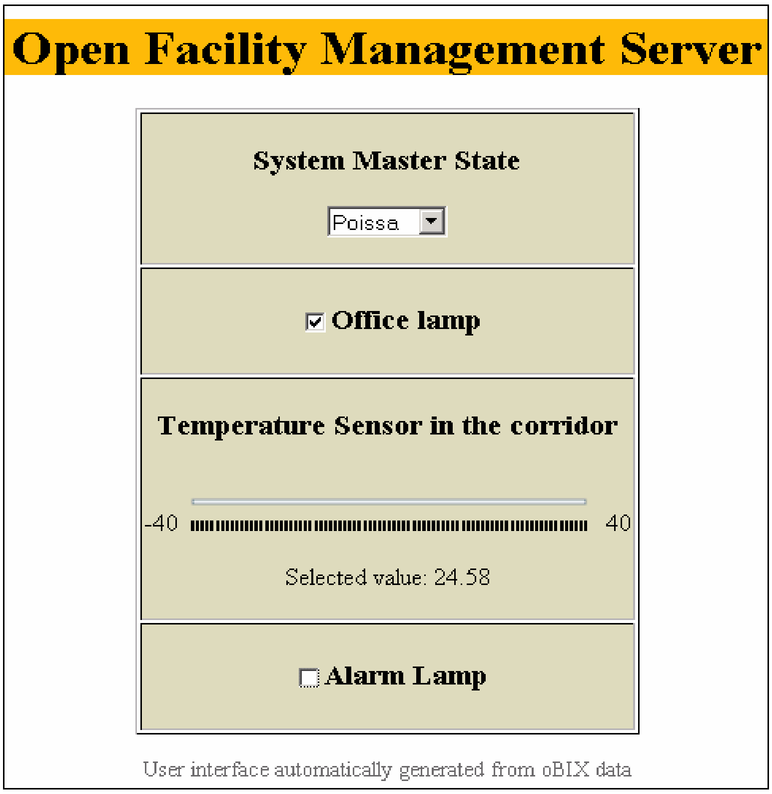


Figure 7.1 Open Facility Management Server

Web Server application design shows the frame that supports the interface in order to interact with the Network Equipment. First and second drawers contain two different adapters used by other application at STOK's Porvoo facilities.

Third and fourth drawers belong to the Linet network application. To implement them in the Web Server one has to load in the equipment adapter contents of oFMS program.

Once compiled the *EquipmentServer*.java execution starts the test.

7.4 Results

The testing can be done when the whole software and program applications pack are running.

The Web Server was charged with two oBIX Point formats from the independent Adapter solution. Analysis of Figure 7.1 shows how the EquipmentLogic understands the Adapter information format. Drawer names are the contained in "display name" place from the Points objects. The different drawer formats are due to the different Point types in oBIX format. In fact the value within “Temperature Sensor in the Corridor” drawer is the last value stored before loading Point format from Web Server.

Web Server application is still not ready for RealPoints type of oBIX Points. Nevertheless the BoolPoints type is already developed and it supports the test so the test is done only using the fourth drawer.

If the checkbox is clicked, in the Lamp Test it is observed the Node 9 Lamp turning on. This node that corresponds to the Boolean Linet Group is the named “Test Lamp”. The turning on of the lamp demonstrates the correct work of the *setPoint* method. With this function the loaded frame in the Adapter contains a true value which does the change in the node status.

If the checkbox is clicked again the setPoint works again resetting the previous sent value. In both tests exists a short delay time which is product of the necessary time to understand the new status and charge it physically by the node.

Unfortunately the getPoint function is still not ready programmed in the Web Server, and no interface allows showing a *getPoint* execution result. One attempt to achieve a solution is by refreshing the navigator in order to obtain the presents values through *getPoints* application, but this attempt was frustrated by the oBIX Points inheritance in the used toolkit. Despite to the first idea, the *setPoint* operation works with fewer problems than *getPoint* operation.

The interface created has been not developed as whole solution which could show all the IEquipmentAdapter method potentials. The main problem for the Web Server application development was lack of time. Other handicap to overcome was the toolkit which was under development. They are the reasons why the other test could be performed. This other tests consist of *getPoint* and *getPoints* methods, which would cover the part which is entrusted to load data from the network to the EquipmentLogic.

Besides the own test, during the programming development other resort had been performed in this sense.

The *EncoderAndDecoder* class in the *adapter.frameCreator* package contains this resort. It consists of implementing a tool able to decode and encode the XML information format in a physic XML document in the computer hard disk memory. The selected folder to save the file can be changed freely in a String file in the program code.

This way has been proposed in order to help the program development but at the end it had resulted being a possible tool for the *EquipmentServer*.

7.5 Suggest Solution

One solution has been proposed in the presence of the refreshing data’s problem in the Web Server application. This solution consists of the use of some specific class from our program code.

The suggested classes are in *linet.java* package. They are the set of *LinetEvent* and *LinetEventListener* classes. The solution would require the use of these methods. These classes are in charge of handling the exceptions throwing when any variations are detected in the network state. *LinetEventListener* is the interface that contains the call to *LinetEvent* class.

In the application operation the throwing of this class is generated by *analyse* method from the *LinetImpl* class. Changes cause exceptions which inform about its node group number and state value.

Chapter 8

Conclusions

At the beginning of Master's Thesis objectives were set. At the end of this project work most of them can be considered as fulfilled to be met.

The context under which the work is developed gives name to this Master's Thesis. It is the Home Automation field and its component areas. Home networking and home server platforms stand out over others. The tested model for Home Automation was composed by both of these areas.

The example carried out it is a good implementation of two new technologies in each one of these fields, home networking and standard home server protocol platforms.

The motivations for choosing this technology have been:

Regarding to home network, the Linet technology features fitted the necessaries aims by the Home Networking system proposed. The easiness of work with something already installed saving installation times of new equipment is a good reason too.

The Open Building Information Exchange platform, oBIX, has been selected among a wide range of possibilities. Its qualities in the XML information frame handling are a powerful tool in the communication horizon, but the possibility of cooperation with TML department in a global project with future expectations finished tipped the balance to oBIX choice.

The work done is only a small example about what a Home Automation system can do. They will be in our daily life covering most of things around us. Home Automation technology will be in our work places, buildings, transport vehicles and in our own homes.

Home Automation is being developed rapidly around the world. People are interested in improving the place that supports their lives, their family, and themselves: their home, sweet automated home.

Appendix A

Linet Nodes Position

The next appendix section are about the equipment localization in the Automation Technology Laboratory

A.1 Linet Controller Position

The Linet Controller of the Linet department Network, LIC04 model, is located in the point A in the Figure A.1. It is placed in room 2547.

A.2 Linet Nodes and Device Position

- **Point A**
This point marks the position of the Node 9, directly connected next to the Controller.

- **Point B – The mail box set**
This point marks some Nodes position. The nodes number 2, 4and 5 are placed in the mail box set. The lamp of node 2 group is also there.

- **Point C**
This point marks the node 1 and its output lamp. Both of them are installed in the ceiling. Only is visible the lamp.

- **Point D**
This point marks input signal sensor of the node 1. It is installed in the interior door working together with the door know.

- **Point E – The coffee machine set**
This point marks some Nodes position. The nodes number 7 and 8 are placed in the coffee machine box set.

- **Point F**
This point marks input signal sensor of the node 10. It is installed in the interior door working together with the door know.

- **Point G**

This point marks the node 10 and its output lamp. Both of them are installed in the ceiling. Only is visible the lamp.

A.3 Department map

Figure A.1 shows the department map whit the Linet actors in the network.

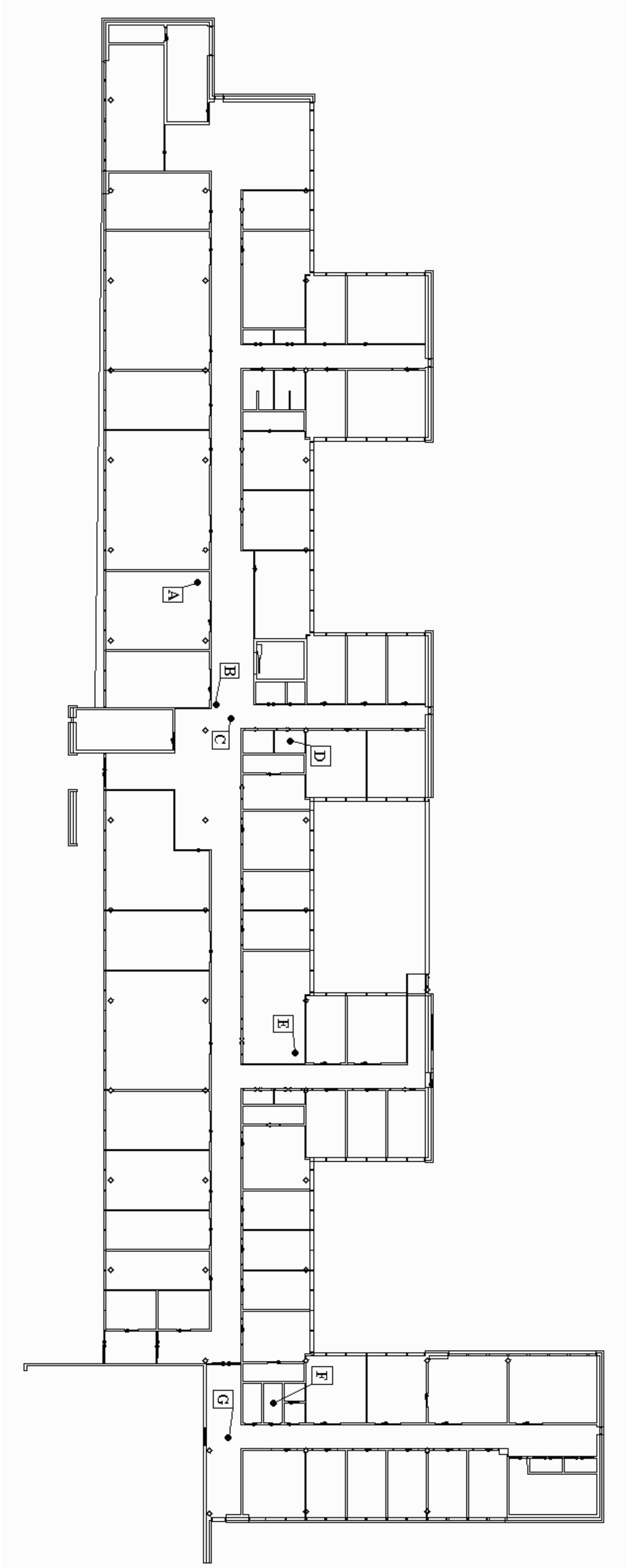


Figure A.1

Appendix B

Linet

Among all the Automation Technology Laboratory networks, this project has used two of them: Linet and Ethernet. Main characteristics of Linet will be described in this appendix.

Most of this chapter contains had been taken from Linet Web Page and the Linet documentation within it.

B.1 The Linet Network

The Linet (from LIght control NETwork) network system is a new technical innovation helping electronics designers to plan and implement application specific control and slow data networks.

“Linet is an easy, reliable and low cost network between electrical devices. It is a light and easy local operational network system. Linet is used to control simple devices (relays, heaters, sensors, etc) without the need of developing application specific software, investments in development tools or learning. Linet is specially designed to address the needs of small and medium systems allowing them to control a network of electrical driven or controlled equipment and various types of data acquisition. The application area range goes from industrial data and process control to home automation” [B.1].

“The Linet light network system consists of a light twisted-pair cabling system, which transmits control information and data from nodes (Linet nodes) to nodes in the network, and a control unit for the network (Linet controller). The nodes link simple devices into the network. The ready-made functions, such as ON/OFF, are used to transmit the functional signal from a selected device via the Linet nodes and network to another device of your choice.” [B.1].

B.1.1 Linet Nodes

The nodes are the building blocks in the Linet system. They are an extremely simple-to use network adapters for the Linet local operation network. The node provides the network interface, the internal power supply, and the ready made I/O functions on a single silicon chip. Main Linet node characteristics are [B.2]:

- Ultra low power consumption (4 mW)
- 3 mA current output capacity

- Polarity free network connection
- Integrated switch input/output function
- Integrated power control output function
- Integrated serial data output function
- Internal 12-bit A/D (Analogical/Digital) converter

“All nodes include all Linet functions. The function to be activated on each node is selected while the network is configured. Many of systems are completed by using just the basic I/O functions, so they are made up and running without writing a single line of software. Applications requiring distributed intelligence can be developed by placing any microcontroller next to the node, and then using the Linet system to transmit raw serial data between the microcontrollers, or between the microcontroller and a host” [B.2].

The network cable in the Linet system is single twisted pair cable. Both data and operating power required by the nodes are transmitted in the same single pair. The cabling is totally topology and polarity free, and no terminating resistors are needed. This provides a maximum flexibility in designing, installing, and modifying the network.

B.1.2 Linet Controller

“The controller is an intelligent power supply for nodes in the network. It is the logical link between nodes in the network, and between nodes and the host. It also provides network configuration services, eliminating any Linet-specific design or configuration tools necessity” [B.2].

A Linet network is really simple to configure [B.3]. No Linet-specific tools are required. The Linet controller provides the necessary functions to configure and administer one network. Various user interfaces could be used for this, like a PC or other computer running a terminal application or web browser, or a fixed interface consisting of an LCD display and pushbutton soft keys. The interface is required only when the network is configured and can be connected at run-time. The main characteristics of the controller are resumed in next lines [B.2]:

- Supplies power to the nodes in the network.
- Supplies carrier and timeslots to the nodes.
- Offers the services to configure and administer the network.
- Can operate as a user interface.
- Operated stand-alone, or forms a link to host systems.

B.1.3 Internet connection accessibility

“Linet network offers a real-time connection between up to 200 nodes. These networks may operate stand-alone, when the application consists of a single or many discrete systems. In many applications, however, remote accessibility or expandability is desired.

To make systems of more than 200 nodes, or to use one ore several Linet networks to a host computer, it is necessary to use the Linet controller's Ethernet connector. With this connection, Linet systems can be linked to Internet or intranet networks.

Instead of locating IP address into every light bulb, Linet is used to collect information from up to 200 simple devices and transfer onto a high capacity information system. This approach combines the benefits of both technologies as the easiness, cost effectiveness and real-time features of Linet systems with a commonly used, standardized IT infrastructure" [B.2]

B.2 Network configuration

In a Linet system, the network controller is used as the tool to set up the network. The controller supports two alternative interfaces for this, which are the fixed user interface and the terminal interface. An interface is required during set-up only, so the user may disconnect it when the configuration has been done and the network is running.

The network configuration using each of mentioned interfaces is clearly explained with step-to-step explanations in Linet web documents [B.4].

After a correct configuration, the installation test is done parallely to installation of nodes in the network. The information about how to add nodes to the network can be found in "Lamp test" document within the last mentioned configuration document. It is a simple procedure used to inspect the correct installation of the network from the Linet controller applications library.

B.2.1 Linet groups

Linet networks are configured using the controller. In this process, nodes in the network are assigned to "groups", each of which are assigned to perform one of the Linet functions. Although all nodes can perform all Linet functions, only one function is active in each group. There are two main group classifications, basic and additional groups. Both of them are shortly explained in Table B.1.

Group Type	Description	Application Example
Basic groups		
Toggle	Each node within a toggle group has a binary state, which is common to all nodes within the group. The state is inverted when there is a rising edge detected on a switch input on any of the nodes within the group.	Lighting group
Analog Input	Each node contains an integrated 12-bit A/D converter with internal, 1.25 V reference. When in use, the converter performs the conversion and feeds the resulting 12-bit figure to the network.	Temperature sensor
Dimmer	Each node within a dimmer group outputs a state, which is common to all nodes within the	Lighting dimmer group

	group. An input switch connected to any of the nodes may be used to control the output.	
Data group	Each node is capable to receive and send binary data at constant rate. Data exchange with network controller can be done with 8, 12 and 16 bits words.	Communication units
Additional groups		
I/O-node	Toggle node is an individual I/O device, connected to one input and one output.	Lighting master switch
Lamp	Lamp nodes are used to control a load. They may be used as slave to dimmer or toggle groups.	Principal lighting systems
Call	A call node puts its output to ON and generates a “call at grid” message on the controller. Once it receives the acknowledgment, it turns its outputs OFF.	Alarm systems, hostess call systems
AD/State	The A/D state node is an analog input switch node	Combined humidity and temperature node
Control	Control groups are used to replace thermostats when controlling temperature (or other magnitude). An input value coming from other sensors, applied to the control, is converted to centigrade.	Heat control systems
Delay	Delay group allow introducing a delay between sensor reaction and actuator effect.	Add delay time to applications

Table B.1 Linet device groups [B.3]

B.3 Protocol

The controller accepts IP/UDP connections and only transmits data on demand. “The IP/UDP protocol is run on the 10BASE-T Ethernet connection to the controller” [B.3]. The controller uses one UDP port. The port number and IP address of the controller are configured during controller setup.

The controller asks to the network as a request packet. Each request packet is answered back to the IP address and port included within the request packet as sender information. The controller can respond to multiple requesters.

“The controller receives and sends packets in binary format. Data entities are 8 or 16 bits unsigned integers. The same data structure is used to send and receive data to and from the controller, only one bit changes to indicate if the packet is a request or an answer, or to indicate a node updating or reading request” [B.3].

A transmission consists of a header that gives global information and 200 network status packets describing each node of the network. Transmissions with less network status packets are possible to increase the available response rate of the controller, but, as in our case, only one computer, the gateway, is connected to the controller.

B.3.1 Packet description

Packet format is described next. Every transmitted packet starts with the following common header:

Byte offset	Byte	Field
0	1	Protocol version.
1	1	Packet type, see below.
2	2	Flags, reserved.

Table B.2 Linet packet header.

The defined packet types (second byte) are defined in Table B.3.

Byte	Packet type
0	Status request
1	Status response
2	Structure request
3	Structure response

Table B.3 Linet packet types

The network status packets structure is defined in Table B.4.

Byte offset	Byte	Field
0	1	Group type, see below
1	1	Flags
2	2	Group value

Table B.4 Network status packet.

The flag fields contain only one flag. If bit 0 is on, the request wants to change the group value state to the value in the packet. If the flag bit 0 is off, the value field is ignored. The group types are the ones defined earlier, and are collected in Table B.5 with its type code.

Type code	Group code	Value type
0	NONE	None
1	TOGGLE	On/off
2	DIMMER	0=off, 1=on, 2=step, and 3=step down
3	IOGROUP	1 bit I/O
4	XLAMP	1 bit I/O
5	LMON	1 bit I/O
6	XDELAY	16 bit delay value in milliseconds
7	WCALL	Waiter call
8	DATA EXCHANGE	Not usable
9	DATA 8	8 bit data value
10	DATA 12	12 bit data value
11	DATA 16	16 bit data value
12	AD/STATE	AD value(12 bit)
13	CONTROL	AD value(12 bit)

Table B.5 Linet group types

Appendix C

oBIX

Home automation standard used in the Master's Thesis application is introduced in this appendix together with its main features.

C.1 Introduction

"Open Building Information eXchange (oBIX) is the result of oBIX Technical Committee (TC) formed at OASIS. Organization for the Advancement of Structured Information Standards (OASIS) is a global consortium that drives the development, converge and adoption of e-business and web services standards" [C.1]. The oBIX TC target is to define a standard web service protocol to enable communications between building mechanical and electrical systems and enterprise applications. This protocol will enable facilities and their operations to be managed as full participants in knowledge-based businesses [C.2].

"The OASIS oBIX TC will continue work previously hosted by the Continental Automated Building Association (CABA) in an XML/Web Services Guideline Committee". TC group include representatives from Cisco Systems, Clasma, Echelon, LonMark International, Tridium, among others [C.3].

Most mechanical and electrical systems are provided with embedded digital controls (DDC) and most of these devices are low cost and not enable for TCP/IP. They are installed with communications wiring. Larger DDC controllers provide network communications for these dedicated controllers. There are several well established binary protocols that are used on these dedicated networks. "While these binary protocols can be used over TCP/IP networks, they have challenges with routers, firewalls, security, and compatibility with other network applications. There is an added challenge in that the industry split between several largely incompatible protocols. This is the motivation for the technical oBIX TC work, which proposes to develop a publicly available services interface specification that can be used to obtain data in a simple and secure manner from HVAC, access control, elevators, laboratory equipment, intruder detection, utilities, and other building automation systems, and to provide data exchange between facilities systems and enterprise applications" [C.4].

C.2 Framework

The oBIX framework simplifies software configuration by providing a standard means, of encoding configuration data in XML. It provides a host of powerful, yet simple, features that simplify the representation, and use of configuration information. "These features, to name but a few, include the ability to represent complex configuration data (file) trees (by providing links between configuration documents), modularization of configuration data, automatic change detection and auto-reload of configuration data, simple integration into Java applications using little or no custom code, support enterprise scale (J2EE) applications, configuration event listeners, a flat learning curve, and extensibility" [C.5].

The importance of software configuration cannot be overstated. "It enables to quickly change the behavior without resorting to code changes. Such behavioral changes are not limited to the mundane, such as database connection strings, but incorporate more complex switching parameters that can be used alter the behavior/logic/flow of code without resulting to compile-dependent changes" [C.6].

While the Java J2SE SDK provides standard mechanism, such as properties files and resource bundles, to enable the configuration of software, this framework offers a great number of features which are required for today's dynamic and complex business environments.

C.2.1 Feature summary

The advantages of the framework over traditional configuration mechanism can be summarized as follows [C.5]:

- ***Use of XML configuration files***: oBIX enables the condensation of sparse, complex and rich data in structured XML file, thus ensuring the portability of the data.

- ***Support for componentization/modularization of configuration data***: It enables modularization of configuration data, thus enabling definition of relationship (via links/import) between configuration documents.

- ***Easy to use API***: It provides simple API, and host of extensions covering JMX and J2EE, which simplify the integration of the framework into the application. These extensions and API, in essence, provide multiple deployment models catering for different application environments.

- ***Support for Java specifications and other open source API***. Support and easy integration into the Java Naming API. The framework provides extensions which are built around Java standards such as the servlet specification (JMX and JNDI).

- ***Extensibility***. Attending to information technology changes, oBIX supports the real-time auto-detection of changes to configuration data, and the real-time auto-reloading and re-synchronization of changed/modified configuration files.

- ***Free use of binaries and open access to source code***. It provides a simple plug-in mechanism, which enables application developers to tap into the framework. This plug-in mechanism is used to develop utilities to simplify the use of a host of other source frameworks.

The framework is intended to serve as "one-stop-shop" for software configuration functionality.

C.3 Architecture

"oBIX is much more than just a way to describe points, historical trends, and alarms" [C.5]. It is an extensible model that describes other models (a meta-model). "oBIX allows control vendors to fully describe their proprietary systems and allow enterprise to discover non-standard data and invent new applications for it" [C.5].

Extendibility is woven into the oBIX structure using the contract. In oBIX, contracts capture the system patterns, as classes do in every software domain or tables do in relational databases. Contracts are used to describe standardized structures such as points, historical trends and alarms.

"oBIX is unique in another regard, it is binding agnostic. There is not only a SOAP binding so oBIX can interoperate with WS (the Web services stack), but also there is an HTTP binding making oBIX a RESTful standard. REST (REpresentational State Transfer) is the architectural style of the World Wide Web. oBIX servers can be accessed with a web browser and therefore can be indexed by search engines, linked to by other web pages and basically interoperate with any other mainstream web technology" [C.7].

C.3.1 Object Model

"All information in oBIX is represented using a small, fixed set of primitives. The base abstraction for these primitives is cleverly called object". An object can be assigned to a URI and all objects can contain other objects. There are eight special kinds of value objects used to store apiece of simple information [C.8]:

- *Bool*, stores boolean value, true or false.
- *Int*, stores an integer value.
- *Real*, stores a floating point value.
- *Str*, stores an enumerated value within a fixed range.
- *Abstime*, stores an absolute time value (timestamp).
- *Realtime*, stores a relative time value (duration or time span).
- *Uri*, stores a Universal Resource Identifier.

Any value object can also contain sub-objects. There are also a couple of other special types: *list, op, feed, ref,* and *err*.

These object types map one to one an XML element type. The oBIX object model is summarized in the following illustration, figure C.1. Each box represents a specific object type (and XML element name). Each object type also lists its supported attributes.

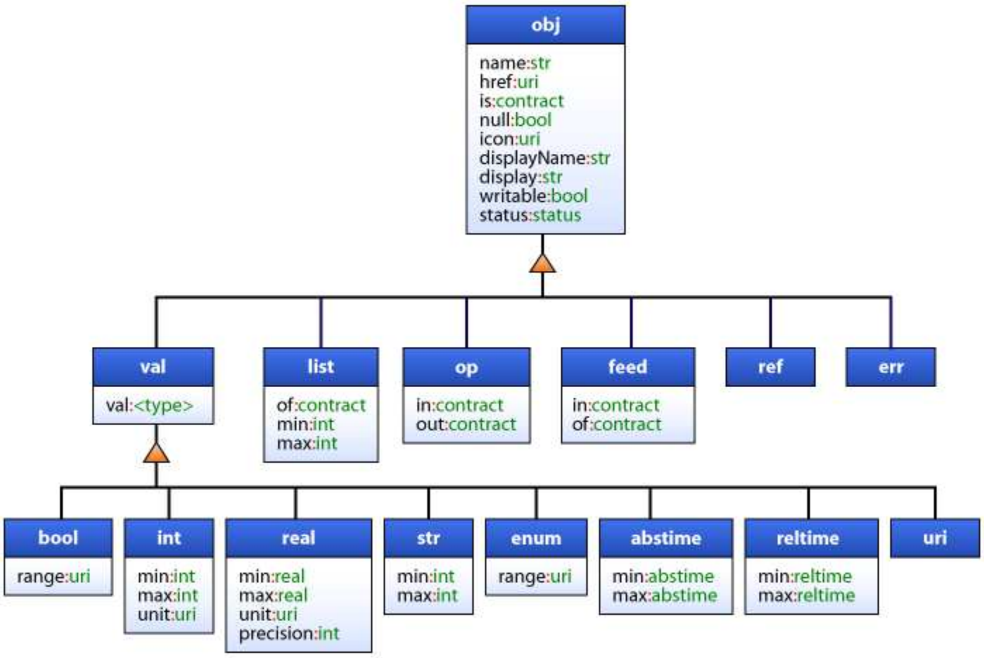


Figure C.1 Object model schema [C.8]

C.3.2 XML

"oBIX is all about a simple XML syntax to represent its underlying object model. Each of the object types map to one type of element" [C.9]. The value objects represent their data value using the *val* attribute. All other aggregation is simply nesting of elements. A simple example to illustrate is Figure C.2 next.

```
<obj name="IN7" is="obix:BoolPoint obix:Point" display="Group Number 7"
   displayName="Working Coffee Machine Sensor" writable="true">
   <bool name="value" val="true" display="Heating the coffee"
   displayName="I/O GROUP" />
   <obj name="status" is="obix:Status" display="group status">
         <bool name="overridden" val="false" />
         <bool name="disabled" val="false" />
         <bool name="fault" val="false" />
         <bool name="down" val="false" />
         <bool name="inAlarm" val="false" />
         <bool name="unackedAlarm" val="false" />
         <bool name="historyStart" val="false" />
         <bool name="historyEnd" val="false" />
   </obj>
   <abstime name="timestamp" val="1970-01-01T02:00:00.000+02:00" />
 </obj>
```

Figure C.2 oBIX object example corresponding to department coffee machine node

The particular XML design philosophy, syntax (very closely to the abstract object model), encoding, decoding, and other particularities as namespace are completely extended with clearly and examples in the working draft together with the rest of oBIX specification.

C.3.3 URIs

No architecture is complete without some sort of naming system. In oBIX everything is an object, so a way to name objects is needed. Since oBIX is really about making information available over the web using XML, it makes to sense to leverage URI format (Uniform Resource Identifier) [C.10]. URI is the standard way to identify "resources" on the web.

"Often URIs also provide information about how to fetch their resource, this is the reason why they are often called URLs (Uniform Resource Locator). From a practical perspective if a vendor uses HTTP URIs to identify their objects, you can most likely just do a simple HTTP GET to fetch the oBIX document for that object" [C.8].

The value of URIs are that they come with all sorts of nifty rules already defined. For example URIs define which character are legal and which are illegal. An oBIX great value is URI references which define a standard way to express and normalize relative URIs.

Other details about naming, Href, HTTP relatives URIs, and fragment URIs are largely explained with their corresponding rules in oBIX documents, always parallely with usual URI normative in other cases.

C.3.4 REST

Considering objects identified with URIs and passes around as XML documents, it is logical to be speaking of REST. "REST stand for Representation State Transfer and is an architectural style for web services that mimics how the World Wide Web (WWW) works" [C.11]. The WWW is basically a big web of XML object documents hyperlinked together using URIs.

"REST is really more of a design style, than a specification. REST is a resource centric as opposed to method centric, resources being oBIX objects". The methods used tend to be a very small fixed set of verbs used to work generically with all resources. In oBIX all network requests boil down to three request types [C.11]:

- Read, an object.
- Write an object.
- Invoke an operation.

C.3.5 Contracts

In every software domain, patterns start to emerge where many different object instances share common characteristics. For example in most systems that model people, each person probably has a name, address, and phone number. In vertical domains we may attach domain specific information to each person. For example an access control system might associate a badge number with each person [C.8].

The most important use of contracts is by the oBIX specification itself to define new standard abstractions. It is just as important for everyone to agree on normalized semantics as it is as on syntax. Contracts also provide the definitions needed to map to the oriented object classes or the relational database tables.

C.3.6 Extendibility

The principle behind oBIX extendibility is that anything new is defined strictly in object terms, URIs, and contracts. To put it another way, new abstractions don't introduce any new XML syntax or functionality that client code is forced to care about. "New abstractions are always modeled as standard trees of oBIX objects, just with different semantics. That doesn't mean that higher level application code never changes to deal with new abstractions, but the core stack that deals with networking and parsing shouldn't have to change" [C.8].

This extendibility model is similar to most mainstream programming languages such as Java or C#. The syntax of the core language is achieved by defining new classes libraries using the language's fixed syntax. This means it is no needed to update compiler every time some one adds a new class.

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